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**AN INTEGRATED DISPLAY AND CONTROL SYSTEM
FOR MAN-MACHINE COMMUNICATION**

CURTIS G. LAWSON

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AN INTEGRATED DISPLAY AND
CONTROL SYSTEM FOR MAN-MACHINE COOPERATION

Curtis G. Lawson

AN INTEGRATED DISPLAY AND
CONTROL SYSTEM FOR MAN-MACHINE COMMUNICATION

by

Curtis G. Lawson

Captain, United States Marine Corps

Submitted in partial fulfillment of
the requirements for the degree of

MASTER OF SCIENCE
IN
ENGINEERING ELECTRONICS

United States Naval Postgraduate School
Monterey, California

1962

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ABSTRACT

Computer oriented systems have created the need for a closer interaction between men and computers. This thesis is an evaluation of, and the resulting system design of one such system. The main portion of the design is that of the operator's display and control console for this system. Included as a portion of the design problem is a computer program for the mechanization of wiring data for constructing the digital equipment.

The operator's display and control console is presently being constructed by Data Display, Incorporated of Saint Paul, Minnesota.

The author wishes to express his appreciation to Professor Mitchell L. Cotton of the U. S. Naval Postgraduate School, and to Mr. G. N. Grashorn of Data Display, Incorporated for their many helpful suggestions.

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1. Man-Machine Communications in a Digital System

The present use of computers in most applications can be classified as one of two categories:

a. Off-line operations in which a preformulated problem and precoded groups of data are fed to the computer along with the programs for processing the information. The computation then proceeds according to the preplanned program, if all data and programs are correct. Upon completion of a successful program, the desired results are then dumped from the computer memory to an output media for printing and evaluation at some later time. The extension of this technique has led to the "closed shop" computing center with their various "auto-monitor" programs in which the individual who wants the problem solved never sees the computer. This technique was prompted by the expense of large digital computers. The major drawback to such a scheme is that in writing new programs or trying to formulate new techniques for solving problems, there is a good chance for errors which will not allow the program to run to completion and may not give any indication of the reasons for stoppage. The cost of off-line formulation and "de-bugging" may be considerable in some circumstances.

b. On-line operations in which the operator is working in real time with the computer on a real time physical problem. This type of operation traditionally employs programs which are necessarily complex to take every possible situation into consideration. The role of the man in this system has been to make simple "yes-no" or similar decisions and to provide a means of accomplishing tasks

which are not automated or programmed whether by reason of difficulty or just oversight. Examples of on-line operation are the military systems (i.e., MAGL, RTDS, etc.) and industrial process controls. The cost of such systems are large as the computer is usually in full time use by the system due to the special purpose nature of the equipments.

There has been a recent trend to explore the possibilities of utilizing the best points of both techniques in systems linking man and computer more closely /1, 2/. In order to accomplish this, the basic class of operation must tend toward on-line operation. By having a closer link with the computer, the operator can make decisions at various points in the process based on real time feedbacks; examine changes in results due to varying inputs or parameters in real time; program and check blocks of codings easily before integration into a more complex program; and call up and inspect large blocks of information randomly from a large memory.

In order to accomplish this interaction between man and computer while keeping the overall system flexible and relatively inexpensive, certain requirements must be met: (a) A method of time sharing of the central computer must be implemented whether by programming or hardware techniques. (b) Display and control equipments must be designed to allow the operator to effectively communicate complex ideas to the computer and to allow the computer (through proper programming) to make requests on or display data to the operator. The first requirement is dictated by the desire to perform on-line and off-line computations interlaced in

time, while the second is essential to any closely coordinated man-computer system. The specifications of time sharing systems have been developed in recent literature [28, 29]. It is the purpose of this thesis to develop design criteria and to carry out the design of a display and control console which can be applied to many different type problems.

In a computer oriented system the flow of information is as shown in Figure 1-1.

The man-computer interface consists of two unique parts. There must be a provision for the operator to communicate his desires to the computer, and the computer should have the provision to display results or ask for further instructions. Specific techniques for accomplishing these functions will be discussed in Chapter 2.

In order to intelligently use any or all of the possible information available in a complex system, the display must be able to select various portions of information readily and easily. This means that the display console itself should be a complex buffer and should be able to control the computer's memory and programs. The main control programs in the central computer should be tailored to the display which in turn should be tailored to the human requirements for ease of operation along with flexibility.

Display updating may be done on any of the following criteria:

- a. Upon receipt of new data by the computer
- b. Upon a real time interval
- c. Upon request from the display console

Priority considerations in the case of radar or automatic inputs

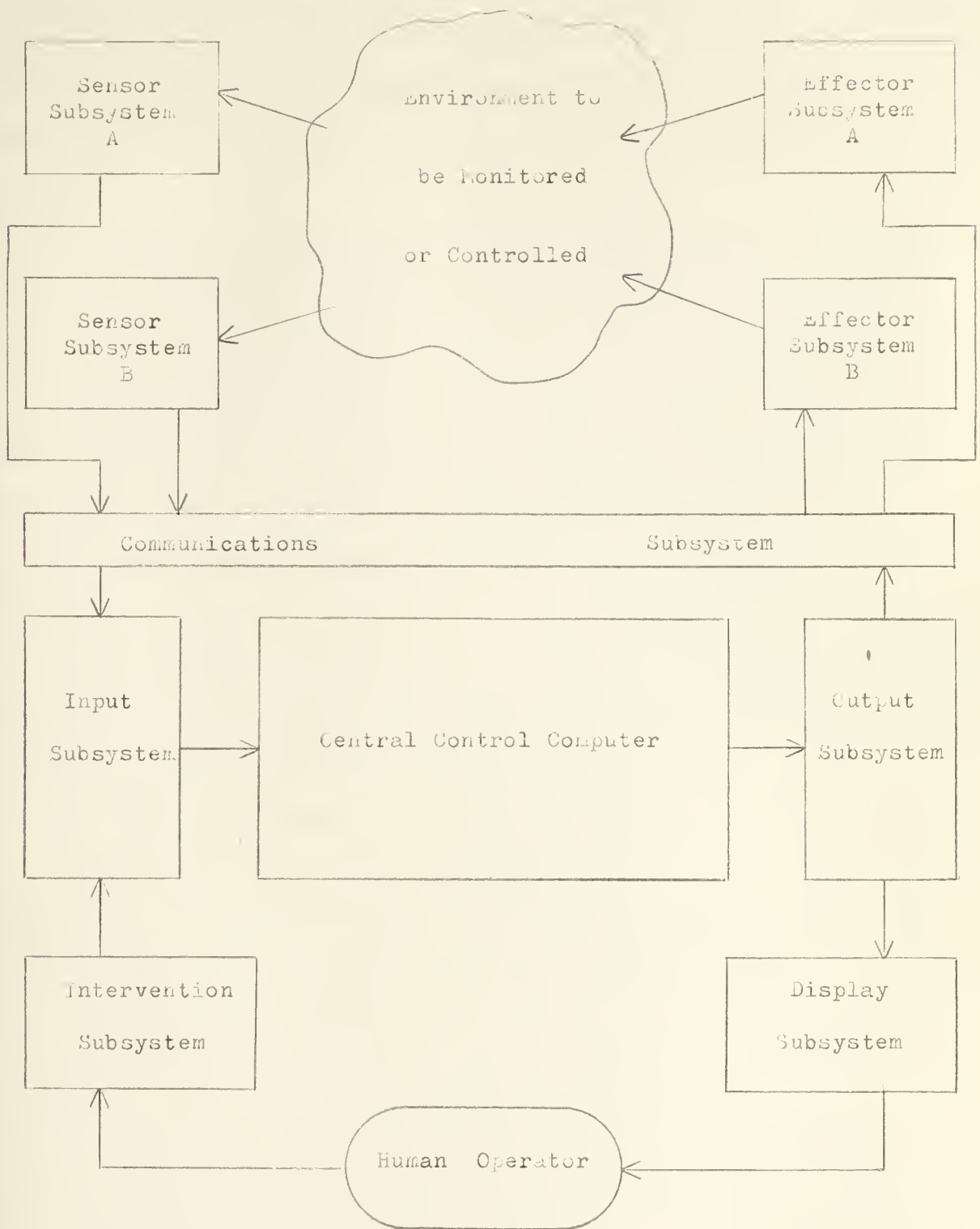


Figure 1-1
Flow of Information in a Man-Computer System

versus manual inputs should also be given consideration in the design of a given equipment. There should be a method for overriding any preselected priority sequence without changing the whole sequence.

The amount of information on a given display must be selectable by the human operator. If there is too much information or unwanted information mixed with the desired information, he must be able to remove some portions of the overall display or be able to expand a part of the display on a secondary display. He should also have control over selective portions of the display in order to view tabular or other information at the same time a graphical display is being produced.

All of these factors should be considered in the design of a given man-computer system with the main guide lines of the actual computer characteristics with which it is to operate.

The broad requirement for an input device is that an operator can readily adapt to it and can communicate his desires to the computer in an efficient manner. This requires that the device be designed using a minimum of controls, but with each control uniquely labeled and preferably able to call in a sequence of sub-routines. The general purpose (stored program) computer is well suited for this type approach. By inserting an executive program into the memory, the control keys can be uniquely labeled to call out and execute desired portions of the program. Then, by changing the executive program, the functions of the controls can be changed. So by changing the labeling of the controls with an "overlay", many

Special purpose control consoles may be simulated. An additional method for specifying information to a computer is that of allowing the operator to draw lines or symbols on a display surface or some input "sketch pad". An interpretive routine in the computer would then have to perform a pattern recognition, curve fitting, or other similar operation before taking action. One other desired control is closely linked to the display or output device. There must be a method for interrogating the computer about a point, a symbol, or an area on a display for the purpose of obtaining amplifying information about the interrogated portion.

The requirements for a display device are imposed by the user. Some of these are physical requirements based on the constraints of human reaction time and visual resolution, while others are based on clarity or recognition of information [3]. These have been listed with a brief explanation of each.

a. Selective display capability:

The computer can generate and hold in its memory a large amount of display information. The operator can intelligently use only a limited portion of the total supply of data at one time. For example, an aircraft controller may only be interested in traffic within a certain block of altitudes; so, he should be able to call in to the display only the representation of those aircraft within his volume of control.

b. Fast response to commands:

When asking for a new piece of information on a display or when dropping some outdated display, the response to the

command should be fast enough to allow continuity of thought for the operator. He should not have to wait for the command to be executed and the display changed.

c. Number and size of the display devices should fit the usage requirements:

In a large system several individual operators may be needed for specific tasks. This function may best be implemented by using a group of individual operator consoles working on data from a central computer and display generator. In some systems, a group of specialists may want to arrive at an optimum decision based on information on a central display. For this purpose, a large screen display is necessary with a possibility of inputting commands from one or more input devices.

d. The display should not flicker:

The retention of images by the eye is such that if a display is refreshed at a rate of about 30 frames per second, no flicker will result. The flicker of a display will be dependent on the storage time of the display elements. For example, if a long persistence phosphor is used in a cathode ray tube display, the refresh rate requirement is reduced, but the time required to change the position of any point on the display or the whole display is determined by the decay time of the phosphor. This decay time is dependent on the initial intensity of the display.

e. Resolution of the display should be greater than the resolving power of the eye:

The eye can discriminate parallel lines separated by

intervals equal to the line width to a value of 60 lines per degree. So for a single operator console, if the display surface is considered to be the base of an isosceles triangle and the eye to be the apex of this triangle (actually an isosceles cone), approximately 50% of viewing angle is included. This dictates that the display should have at least 2,000 "bins" for unique storage in each direction. To place this into a digital representation for computer generation the resolution should be at least 11 bits.

f. The contrast and brightness should be such that under ambient light conditions, the operator will not be subject to eye strain:

The intensity difference between background and information should be on the order of thirty to one for normal usage. If the ambient light is high, reflections from the display surface tend to "wash out" this contrast. A cathode ray tube display console that is designed to operate in normal room lighting needs to incorporate a fast phosphor that can be raised to a high intensity level without producing an extended decay time.

g. Accuracy and distortion should be reduced to an acceptable level:

In any display system, the ideal resulting display would have perfect registration and focus at all points of the display. This goal is rarely, if ever, attained due to hardware considerations. For example, in a cathode ray tube display there is definite defocusing effect at the edges of the tube as the path length of the electron beam is longer. Also, the voltages to pro-

duce the desired deflections in an electrostatic deflection tube (or conversely the current to produce deflections in an electromagnetic deflection tube) do not vary linearly with the distance from the center of the tube /4/. This leads to the use of compensation circuits in the control circuitry which can reduce these conditions to an acceptable level.

h. The coding should allow for a variety of presentations:

The requirements for flexibility encompass such ideas as color, size, shape, intensity, position and orientation. And blink rate as a means of attracting attention. Most displays require a set of symbols for normal usage. These would be numbers, the alphabet, and any frequently used symbols. In addition, a method of generating lines should be included for forming special symbols or line drawings. These "vectors" should allow for blanking portions of the length while proceeding along a given direction to enable the further coding of lines into dashed lines.

i. The format for the display should suit the usage requirements:

Some examples of formats are textual, tabular, graphical, situation or overlay map plus defining symbols, line drawings and diagrams, patterns of symbols to show complex situations, and pictorial symbols to show the status and condition of remote elements. The general classification can be termed either fixed or free. The fixed format is considered to be a textual or tabular type where automatic incrementing and positioning of symbols is accomplished on a set of constraints mechanized into the hardware.

the free format is usually implemented through a program control feature which must be generated in the computer.

The number of operators and/or viewers of a man-computer console has a direct bearing on the requirements as has been previously noted. For group displays, optical projection and electroluminescent panels have come into usage as the size of direct view cathode ray tubes are limited by deflection techniques. Examples of group displays have been discussed in recent publications /5, 6/. This thesis will discuss only single operator, direct view, non-colored cathode ray tube displays.

2. Techniques for Man-Computer Communication

The methods available for producing commands to a computer are largely dependent on the type computer being used in the system. For normal communications the computer is in control of the data lines, and the executive program must sample the possible inputs at "programmed" time intervals. For priority communications, the operator should have the ability to interrupt the computer and insert the necessary commands. The nature of any input to the computer is one of a digitally coded bit pattern dependent on the setting of switches or digital encoders, and the initiation of a command switch. A good example of this type communication is the console typewriter which can be used for input and output. An exception to this straightforward input technique is that of employing a "sketch pad" in which the input takes the form of movement of a probe over a display or an analog surface. In these cases, the computer must sample the allowable surface at a rate fast enough so that normal motion of the probe by the operator generates a smooth input of coded positional values corresponding to the desired lines being traced by the probe. In the case of a direct view cathode ray tube, the probe is a light sensitive photo-diode, and the computer program must display a raster of points about the last recorded position of the probe. The new point is recorded as a feedback of information of the position in the raster which coincides with the probe.

In order to produce a visual display on a cathode ray tube surface from a computer output, a certain amount of decoding and

processing must accompany each computer word. Principle requirements by the display device for each piece of information displayed are: (a) positional information, i.e., X and Y or ρ and θ with respect to some reference point; (b) coded information specifying character or line type, intensity, and size of symbol or length of line. The display circuitry must be able to decode this information and convert its meaning into the necessary deflection and intensity signals to produce the desired symbol at the specified location.

The symbol formation signals must be superimposed upon the positional deflection signals. This can be accomplished by voltage or current summers in the analog deflection circuitry. The methods of categorizing the various techniques for symbol generators have been listed in recent publications /7, 8, 9/. These are dot pattern, scanning raster, waveforms or strokes, and shaped beams.

In the dot pattern method, the symbols are made by positioning the beam to a sequence of positions defining the symbol. At each point in the sequence the beam is unblanked. The result is a group of dots oriented to form the desired symbol. The formation may use a cell of computer memory for each point displayed as in the PDP-1 console display /10/. This method is limited in speed to the speed of each memory cycle. An analog method for generating the dot pattern has been devised which makes use of resistor networks /11/.

A combination of scanning and the dot method are used by the Laboratory for Electronics in their SA-2 symbol generator. For this method each symbol in the set is represented by a selectable

matrix of magnetic cores. Each core is located at a position where a dot is to appear in the character. The matrix is scanned by rows while the beam is unblanked as a function of the cores.

A variation on the core scanning system is the VIDAC /12/. Each symbol is again represented by a selectable matrix of magnetic cores. In this generator, the cores are positioned so that they make a double outline of the desired character. The selected matrix is then scanned by rows, and alternate cores turn the beam on and off. This causes the figure to be made up of a group of parallel line segments.

The scanning method of forming characters can be implemented by using flying spot scanner techniques /13/. In this method a fixed size scanning raster is moved to a spot on the generator tube which coincides with the desired character on a symbol mask. The portion of the beam that goes through the mask is focused on a photomultiplier, and this signal is amplified to control the intensity grid of the display tube. The scan pattern must be superimposed on the positional information for deflection signals. The combination of intensity and deflection produces the desired symbol on the display.

The stroke method has been used with much success in the "Calliscope" of Lincoln Laboratories /14, 15/, the symbol generator of Strand Engineering Laboratory, and the symbol generator of Data Display, Incorporated. The methods of deriving the deflection and intensity signals for each of these techniques vary considerably, but the results achieved are the same. The symbols are formed by

unblanking the beam at a starting point for each character and then moving the beam while it is unblanked. Some complex symbols require multiple unblanking and blanking during the formation period.

The shaped beam method is used extensively in the military display systems (SAGE and MDS). The basis of the system is the "Charactron" tube /10/. The tube has a character matrix within the tube envelope. The character desired must be selected by positioning the beam to the associated figure in the mask by a small electrostatic deflection system. The beam is purposefully defocused to obtain a large cross-sectional area, and the shaped beam that gets through the mask is in the outline of the selected symbol. This shaped beam is then magnetically deflected to the desired position on the display surface.

A comparative analysis of these systems has been accomplished by Lowe, Bisson and Horowitz /7/. Two systems not included in this analysis are the "Strand" generator and the "DDI" generator. The respective times for generating a symbol with these systems are 40 and 6.6 microseconds. These rates of 25,000 and 150,000 characters per second compare very favorably with the other systems.

In addition to computer generated displays on cathode ray tubes, a common method for the computer to convey information to an operator is through coded and labeled lights. These are extremely easy for a computer to initiate, and providing the meaning is clear, can be an economical and efficient way for the computer to alert the operator. The main drawback for this technique is the relative inflexibility of the feedback and the possibility of

operator confusion if there are an excessive number of lights on the control console.

3. Design Specifications

The technical requirements for an advanced design digital control display console for the Digital Control and Automation Laboratory were stated as follows:

This unit will provide character and symbol display facilities to ether with provision for direct display of radar video signals. In addition, it will function to provide for communications between an operator and a central computer.¹

A research and development contract² was subsequently awarded to Data Display, Incorporated for the design and construction of the unit which has since been designated as the DD-05. The author worked in conjunction with Mr. Gene Grashorn of Data Display, Incorporated to specify and design this equipment. The remainder of this thesis will be devoted to the actual design of the DD-05.

The system requirements are dictated by the equipments that are to be controlled by or input to the DD-05. There are three distinct modes of operation inferred by the requirements:

a. To input radar information and to provide for (1) display of the video in a PPI format and (2) digitizing of any video return which may be determined to be a target by a detection unit so that the computer may act upon the information.

b. To allow the operator to enter information into the computer.

c. To allow the computer to present data to the operator in the form of symbols on a cathode ray tube or by drawing attention to certain input keys by a system of lights.

¹ J. L. Cotton, Technical Requirements Summary, Digital Control and Automation Laboratory, pp. 1, Feb., 1960

² Navy Contract N0bsr 05573

The following radar units currently installed are to act as inputs to the system:

AR/SPS 0

AR/SPS 8

AR/SPS 12

AR/SPS 20

These radars are installed in the main radar laboratory, and the following information must be made available for use in the D-65:

- a. Azimuth information
- b. "Main bang" or time of pulse transmission
- c. Video return signal which will have any targets along with noise introduced in the process.
- d. Height information in the case of the SPS 1 and SPS 20.

This analog information must be converted to digital information for display and further transfer to the digital processors.

The digital computers incorporated in the system are a large scale scientific computer, the Control Data Corporation 1604 /17/ and a small data processor, the Control Data Corporation 160 /18/. These computers communicate with external equipment by parallel data transfer lines which are controlled by a sequence of control signals. Also, an essential part of the system is the Control Data Corporation 1607 magnetic tape system which contains circuits for a "Satellite" operation between the 160 and the 1604 /19/.

In order to perform an output from the computers to one of a number of peripheral equipments, the following sequence must be performed:

a. Communications established with the desired equipment (exclusive of all others) by a coded select signal proceeded by a sense signal to determine if equipment is available.

b. Data transferred to output lines, and a signal output ready is sent to all peripheral equipment.

c. The selected equipment (only) recognizes the ready and accepts the data, and at the same time sends an output resume signal back to the computer.

d. The computer, upon receipt of the resume signal, then drops the data and ready signals and prepares for the next word transfer, if any, or merely continues on the internal program.

In order to perform an input to a computer from an external equipment, the computer program must be written so that it looks to see if any equipment has data ready for input. This must be done by coded sense responses which must be built into the peripheral equipments. The computer, upon recognizing the source and the presence of an input word, then sends an input request signal which signifies that it has accepted the data and allows the equipment to drop the signals for its data lines. This sequence must be repeated for each data word entry.

In the 1604 an additional input mode has been utilized. This is the interrupt mode. This interrupt mode must be preselected by a select code in the program. If the selected interrupt occurs during the program, the program sequence is halted at that point. The address at the time of the halt is inserted into the address portion of the upper half of word number seven of the computer mem-

ory, and a jump is made to execute the lower half command of word number seven (note that the 1604 is a single address, two command per word computer /17/). The memory cell number seven should be set up previously to process the interrupt. This coding should place unconditional jump commands in both halves of the word and the address of a restored subroutine in the address portion of the lower half of the word. This subroutine must be written so that it ends with an unconditional jump to cell number seven. Thus, after having been interrupted, the subroutine is entered, and after processing the interrupt, the control can return to the program step which was being processed at the time of the interrupt.

These then are the physical rules by which the DB-5 was designed to perform its functions of control and display.

Certain other considerations in the realm of flexibility, usefulness and realizability then served to dictate the method of using the basic criteria in the actual system design. These will be listed as a collection of engineering decisions and the reasoning behind them.

The display will have a self-contained memory unit. This requirement is set for the purpose of freeing the computers from constant usage in refreshing the displays. The requirement that the display be refreshed every 50 milliseconds in order to obtain a "flicker free" display is one that is set by the response time of the eye. This dictates that if the display were to display text of 5,000 characters at six bits per character, then the bit rate

would be 960,000 bits per second. The 1604, if only one channel is active, has a maximum transfer rate of about 50,000 forty-eight bit words per second or about 2,400,000 buffered bits per second. The 160 has a transfer rate of about 80,000 twelve-bit words per second or about 960,000 bits per second (unbuffered). Thus, it is seen that the 160 can just barely do the static display at the necessary rate, and if any change is needed in the display, as would be the normal case for moving radar targets, it could not maintain a steady display. The 1604 is not as critical as it has a buffered output, but it still would be taxed in its buffering capabilities if more than a single channel is being used.

The use of a self-contained memory also frees the 1604 from the control subroutines which must be returned to in order to restart a display cycle. This allows more program time for computations. (In a real time air traffic control system with much one aircraft, the computation times are critical.)

The memory package chosen was a 1024 x 24 bit ferrite core memory, licensed from Control Data Corporation. The size was chosen to compromise between the 12-bit 160 and the 48-bit 1604. The cycle time of the memory is 5.4 microseconds which is less than the 6.6 microseconds required to display a character. This allows a new memory cycle to be completed while the last character of the previous word is being displayed. Thus, for all characters to be painted, the total time involved is:

(6.6 microseconds per character) (4 characters per word)
(1024 words per cycle) \approx 28 milliseconds

The difference between the 10 milliseconds required for the 20 milliseconds required for an uninterrupted cycle allows five milliseconds for updating the data each cycle without inducing a flicker.

The intercomputer operation must be selective. In the physical layout of units the Control Data Corporation 1604 and the Control Data Corporation 1607 magnetic tape system are located in the U. S. Naval Postgraduate School computing center on the first floor of the Engineering building. The Digital Control and Automation Laboratory is located on the fifth floor directly above the computing center. The DD-65 and the Control Data Corporation 160 of this system are to be located in that laboratory. Usage requirements dictate that the 1604 will not be available for use at certain times (pending the incorporation of a parallel processing monitor program). This requires a lockout be available for the 1604. Also, the 160 may be required to do full time processing of radar data for the 1604, and the data flow should be via the 1607 satellite system (1607 independent of the DD-65 system). A lockout is required. The result is the incorporation of a selective mode for using the system.

- a. 1604 only (160 locked out)
- b. Both (both computers may establish communications with the DD-65.)
- c. 160 only (1604 locked out)

This is realized by a mode switch on the logic chassis.

The basic format for display information should be sequential and the display should include vectors as well as characters. The

requirements of a display to designate "where" and "what" for each piece of information displayed would at first seem that a format should be as follows:

X position	Y position	information
------------	------------	-------------

The normal usage of information, however, shows that there is usually a relationship between adjacent pieces of information. In the normal typed text or a train line that has been broken up into segments, the location of the next piece of information is incrementally connected to the previous one in some manner. The special case would then be taken as the carriage return for the typed text or the end of a line segment in the above examples. So only at these positions would an absolute location be required.

In the case of characters, the normal mode is to increment from left to right. This mode, along with an incrementing from up to down, has been included in the design.

In the case of vectors, several methods were examined. The generation of the vectors is to be under computer control so that any format using simple computations could be used. The following were the three possibilities:

- a. Given a starting position, let the computer specify a completely variable ΔX and ΔY .
- b. Given a starting position, let the computer specify a limited number of ΔX and ΔY in a coded format.
- c. Given a starting position, let the computer specify ΔX and ΔY in 45 degree increments in coded format for a limited number of lengths.

Methods a. and b. both require buffers or variable length incremental counters in their construction. Also, method a. needs a completely variable intensity compensation over the line length variations. Method c. needs incremental up and down counters only, but needs counting rate changes and intensity compensation for each length of line to be drawn.

The accuracies of methods a. and b. are greater, but they sacrifice packing density, and they require a greater amount of hardware to construct.

Using this criteria (also keeping a six-bit coded vector package to be compatible with the character coding size), the design incorporated was that of method c., but allowing for an extremely short vector so that the error could be minimized if the accuracy was needed. The use of incremental counters also makes easier the sequential designation of vectors for forming continuous lines.

The requirement for both characters and vectors dictated that a bit be set aside in each string designator word for "mode". The details of display coding will be covered in detail in Chapter 6.

There should be two display tubes, only one of which is a direct slave to the radar inputs. Inasmuch as this system is in part being designed to allow investigation on various digital processing techniques in radar detection, the use for comparative displays is desirable. One display tube must be available to display video information at any time between the "main bang" and the maximum range time (if radar input has been selected). During this time, all display information from the internal memory must be

"flooded out" by radar signals, resulting in a loss of target. This limits the amount of synchronization of radar and computer that can be done on the tube. The amount is proportional to the amount of time between the radar input and the start of the next video.

The second tube is independent of the radar inputs and can be used to display processed video, its background maps and amplifying information (such as weight, type, etc.). This tube is always available to the memory of the and can be used in conjunction with the direct radar display.

Future displays could perhaps be built utilizing dual beam electrostatic tubes¹ to remove the restriction on time sharing of radar signals and computer displays.

The manual inputs should allow flexibility. The system is designed to be used with a stored program computer, so a large measure of flexibility is accomplished through the use of stored subroutines. The method of calling in a set of subroutines from a magnetic tape library best allows for different sections of the library to be called in for different uses of the computer. This is best handled by an overlay switch, in addition to other switches to designate the overlay, can change the switch function itself by having the function associated with each switch engraved on the overlay board.

¹ Electronic Tube and Instrument Div. of General Electric Corp., 11034 - 11 1/2 inch diameter, dual beam, electrostatic focus and Deflection Cathode ray tube, rep., 1961

In addition to the usual switches, there are a few touchkeys common to all uses of the console. These are located adjacent to the special overlay function switches, and together they are referred to as keyboard two.

The character keyboard is referred to as keyboard one. This keyboard is made up of all the standard numerals and alphabet, along with special characters to complete the keyboard. These keyboards and their coding will be given full treatment in Chapter 7.

Other manual inputs required are a range switch to control the displayed radar presentation and some method for locating and identifying points on the display. There are two common methods for accomplishing this function digitally:

- a. Track ball
- b. Photo electric light gun

In the track ball method, two shaft position encoders are placed at right angles, and a ball in contact with both encoders allows the operator (by rolling the ball) to position the encoders very accurately. A symbol will have to be displayed under program control whose center is located at the X, Y position given by the encoders. Thus, by calling for the program to display track ball, the symbol may be centered over any point of interest, and then by a second subroutine this information may be used to enter new information or find a memory cell which contains this point for purposes of changing the display.

The method of the light gun accomplishes the same purpose, but it is positioned by hand over a display, and then the light sensi-

tive circuit is energized and the portion of the time face under the light gun is illuminated, a circuit can be made to extract the contents of that memory cell to find the position.

The light gun is faster, and its use is a more natural reaction, but for closely spaced points the track ball with its accuracy is easier to use. Based upon this reasoning, a track ball was used in the DB-65.

The display should allow for an auxiliary output channel to dump radar data. In order to obtain best utilization of the computers, i.e., to let them perform computations at a speed limited by the program (without interruptions for storing data), an auxiliary channel to accept the digitized X, Y (and Z component with minor modifications) has been provided. A buffer memory unit and associated control circuits should be provided between the radar data, and the computer assigned to do the processing. The radar processing computer can then call for targets at its own rate. The buffer memory unit must have a fast access time in order to accept targets at the rate they are received from the radars. The access time needs to be on the order of 100 nanoseconds if no targets are to be missed. This requirement can be met by designing the buffer unit from standard flip-flop circuit. This is economically feasible as the word size is only 12 bits, and the number of storage words needed should be small.

4. Hardware Consideration and Mechanization of Design Procedure

In order to design digital equipments to have high component packing density and at the same time to allow for easy maintenance, the computer industry has developed the following technique. The circuits to be used are specified in terms of type (pulse or level signal) and speed of response desired. From these requirements, a family of circuits can be designed which are compatible and which, by interconnection, can perform the logical functions AND, OR, or NOT. These circuits are then placed on printed circuit cards either singly or in small groups. The system designer then need only know the parameters and limitations of the family of logic cards in order to specify the interconnections necessary to design a particular equipment. The construction is then completed by wiring the interconnections on a chassis made up of logic card sockets. In this way all active elements are on the removeable cards to allow for easy replacement of a faulty circuit.

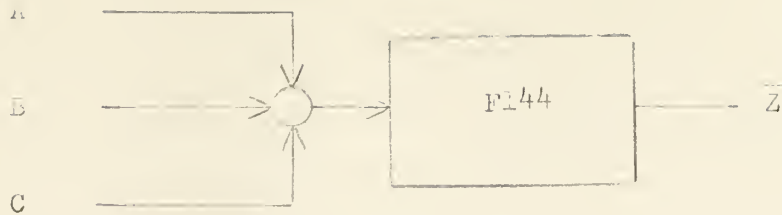
The logic card family used in the design of the DD-15 is mainly the Control Data Corporation type as described in their manuals /17, 18/ and reported on by J. L. Farrell /20/. These cards are designed to operate at clock rates up to five megacycles as level signal inverters. The switching delay is between 50 and 100 nanoseconds per card. Additional cards have been developed by Data Display, Incorporated for the special uses needed in displays. These are in two main categories: (a) Digital to analog conversion cards for driving the display beams and (b) a fast set of cards to work at about 20 mc for the display of digitized raster information.

The digital logic gate is a device which will only be dissimilar in this respect, i.e. a final output which is compatible with the basic system and compatible with the basic system except for more direct or indirect connection.

The logic circuitry used in the basic system is a logic circuit is an inverter with a delay in the output. It is in such a way that (a) a connection to the output of the circuit is made at a single input of another circuit, a logic gate, or (b) by connecting the outputs of the logic gate to a circuit with multiple inputs a logic gate is reduced. Figure 1-1 shows the two basic configurations and the symbols used to denote these functions. These basic functions may be combined to enable the designer to realize any complex logical function desired.

This type of logical definition which may be used to build itself to system design using an initial input of logic functions which are to be implemented. The reason for this is that the three level logic (AND, OR, NOT) which is the basic logic is not easy to reduce without a delay. The method used is to specify the functions through a diagram. In this way a traditional logic may be built up without carrying along the history of the logic functions that would be required. The technique used is equivalent to naming each inverter so that once the design diagram is completed, an equation file can be written in terms of inputs to each inverter.

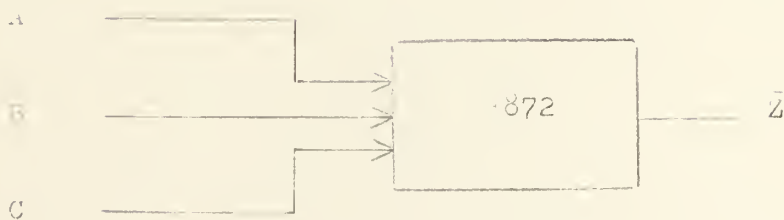
1. comparative system which can be simplified accordingly in the "Sheffer stroke" system.



$$Z = A \cdot B \cdot C$$

$$\bar{Z} = \overline{A \cdot B \cdot C} = \bar{A} + \bar{B} + \bar{C}$$

LOGICAL "AND"



$$Z = A + B + C$$

$$\bar{Z} = \overline{A + B + C} = \bar{A} \cdot \bar{B} \cdot \bar{C}$$

LOGICAL "OR"

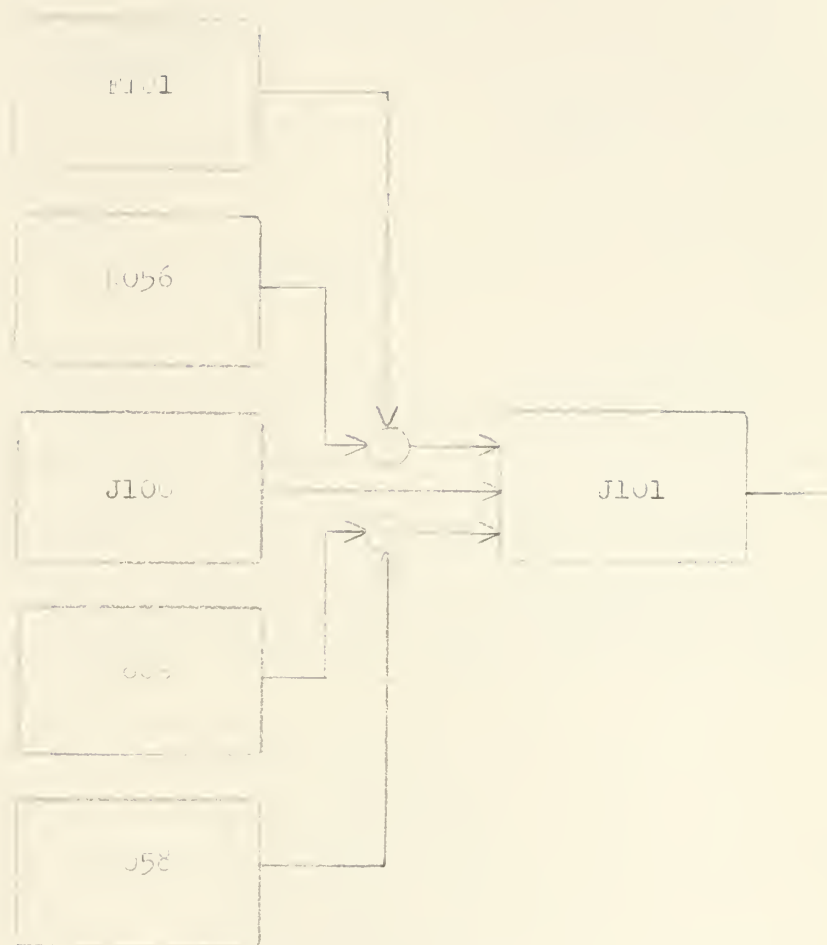
Figure 4-1
Logic Diagrams in Control Data Corporation Notation

This is shown in Figure #2. As the equations are written in terms of inputs, no explicit statement of the inversion is used. When the design diagrams have been completed the individual card types may be assigned based on the number of inputs and outputs. Once the card types have been assigned, the total number of cards needed are uniquely known, and a chassis size may be chosen. In this line of cards there are up to three inverter sections on each card. The chassis layout can then be specified by assigning each card section a place on the chassis. This is done by assigning a row, a column, and a section to each inverter. The assignment is usually a compromise between obtaining the minimum lengths of interconnecting wire and keeping sections of the chassis grouped into areas of logical functions.

The last step in committing a logical design to hardware is the actual assignment and completion of the interconnecting wiring. The wiring constraints are set by the fact that each card socket has only two terminals per pin. This means that multiple AND signals have to be distributed along the wiring 'tree'¹. (See Figure #3). The task of assigning pin connectors in a manner to minimize wire length is very tedious, and the tedium of it tends to cause errors in the production of a wiring tabulation.

The desire to minimize the number of errors induced in the process between the design diagram and the wiring tabulation re-

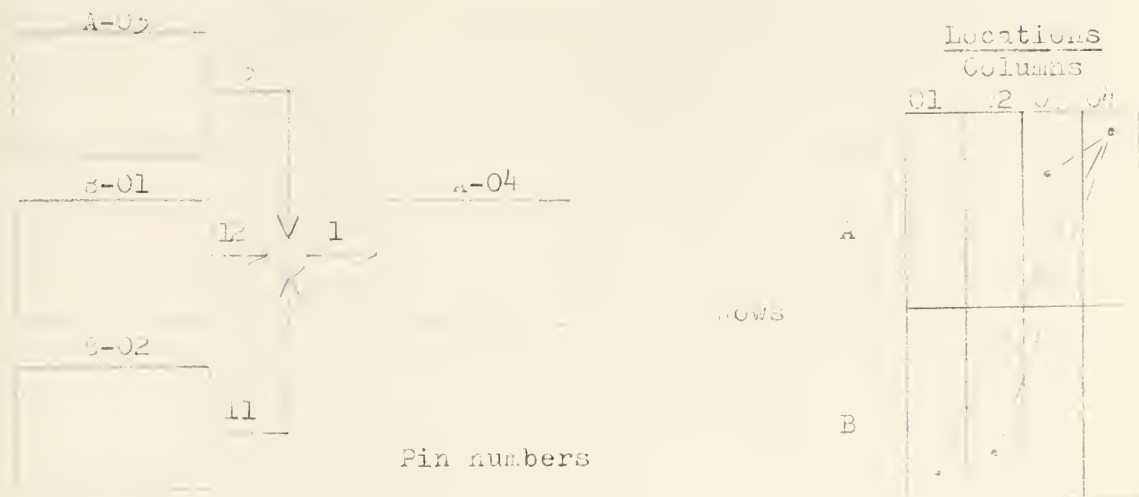
¹a "tree" is a graph having only one path between every two nodes.



$$J101 = J100 + B009 \cdot R056 + R100 \cdot R05$$

Figure 4-2
Example of an equation written from a logic diagram

In order to wire an "n" node of more than two inputs, the following considerations are necessary:



Each connector has only connection terminals for two wires so that the interconnection similar to the depiction in the logic diagram is not possible. The resulting method is to build up complete wiring "tree" by first accepting the smallest interconnecting wire and then building on this base until all "nodes" have been added to the tree.



Figure 4-3
Constraints on Chassis Wiring

sulted in a program which, after minor modifications, was able to perform some of the functions on the Control Data Corporation 1600 computer. The computer has been assigned the tasks of formulating and printing out the completed file of equations and the final minimum wire length wire tabulations. Also, the program will assign card types, call attention to illegal equations, and give a tabular total of the number of cards by types required to implement the design. The necessary inputs are a set of "punched cards" which each contain the equation for a single logic card section and a location for that logic card. The detailed report on usage of the program and an assembly listing of the program is included as Appendix A of this thesis. A sample of the input and outputs are shown in Figures 4-4, 4-5, 4-6, and 4-7.

The method for computing the minimum length wiring to connect a group of nodes is based on an algorithm by Loberman and Weinberger./21/

This program was used in the production of the minimum wiring data for the 50-5. The total card count for the design is over 1500 cards. There are two separate classes which made separate program runs necessary. The time required to compute the complete output listing was less than 20 minutes (exclusive of printing the magnetic tape off-line).

CHASSI DD 65

A000 = A001 + A002 V205 + A101 N009 + A201 N109	J1 J05A
A001 = A000 J842 + A003 V205 + N108 + GNDE	J1 J06A
A002 = A003 + A001 N800	J1 L04A
A003 = A002 + A000 N800 + GNDE + GNDE	J1 J07A
A010 = A011 + A012 A003 V205 + A111 N009 + A211 N109	J1 J05C
A011 = A010 + A013 A003 V205 + N108 + GNDE	J1 J03A
A012 = A013 + A011 N800	J1 K03C
A013 = A012 + A010 N800	J1 K03A
A020 = A021 + A022 A013 A003 V205 + A121 N009 + A221 N109	J1 L08A
A021 = A020 + A023 A013 A003 V205 + N108 + GNDE	J1 L07A
A022 = A023 + A021 N802	J1 L06A
A023 = A022 + A020 N800	J1 L06C
A030 = A031 + A032 V215 + A131 N009 + A231 N109	J1 L08C
A031 = A030 + A033 V215 + N108 + GNDE	J1 L09A
A032 = A033 + A031 N802	J1 L10C
A033 = A032 + A030 N802	J1 L10A
A040 = A041 + A042 A033 V215 + A141 N009 + A241 N109	J1 N08A
A041 = A040 + A043 A033 V215 + N108 + GNDE	J1 M08A
A042 = A043 + A040 N804	J1 M09A
A043 = A042 + A041 N802	J1 M09C
A050 = A051 + A052 V225 + A151 N019 + A251 N119	J1 N08C
A051 = A050 + A053 V215 + N118 + GNDE	J1 N09A
A052 = A053 + A051 N804	J1 N07C

Figure 4-4
Sample of Input to Mechanization Program

CHASSIS 1 DD 65

A000 = A001 + A002 V205 + A101 N009 + A201 N109
 J1 J05A 24 A003, A001,
 A001 = A000 J842 + A003 V205 + N108 + GNDE
 J1 J06A 14 T011, H215, A200, A100, A002, A000,
 A002 = A003 + A001 N800
 J1 L04A 22 T012, T010, A003, A000,
 A003 = A002 + A000 N800 + GNDE + GNDE
 J1 J07A 14 T013, A021, A020, A011, A010, A002, A001,
 A010 = A011 + A012 A005 V205 + A111 N009 + A211 N109
 J1 J05C 24 A013, A011,
 A011 = A010 + A013 A003 V205 + N108 + GNDE
 J1 J03A 14 T013, T012, H215, A210, A110, A012, A010,
 A012 = A013 + A011 N800
 J1 K03C 22 T011, T010, A013, A010,
 A013 = A012 + A010 N800
 J1 K03A 22 A021, A020, A012, A011,
 A020 = A021 + A022 A013 A003 V205 + A121 N009 + A221 N109
 J1 L08A 24 A023, A021,
 A021 = A020 + A023 A013 A003 V205 + N108 + GNDE
 J1 L07A 14 H215, A220, A120, A022, A020,
 A022 = A023 + A021 N802
 J1 L06A 22 T001, A023, A020,
 A023 = A022 + A020 N800
 J1 L06C 22 T000, A022, A021,
 A030 = A031 + A032 V215 + A131 N009 + A231 N109
 J1 L08C 24 A033, A031,
 A031 = A030 + A033 V215 + N108 + GNDE
 J1 L09A 14 T002, H225, A230, A130, A032, A030,
 A032 = A033 + A031 N802
 J1 L10C 22 T003, A033, A030,

Figure 1-1
Sample of Output of File of Equations

U S NAVAL POST GRADUATE SCHOOL DATA PROCESSING LABORATORY

COMPILATION OF CARD ASSIGNMENTS

CARD TYPE NUMBER OF CARDS

11	1
12	NONE
13	NONE
14	210
15	1
16	36
31	NONE
32	NCNE
33	NCNE
21	81
22	204 1/2
23	17
24	29
01	21
61	NCNE
62	NCNE
S36	3 2/3
S04	NCNE

Figure 4-10
Sample of Card Compilation

U S NAVAL POST GRADUATE SCHOOL DATA PROCESSING LABORATORY

INTER CARD WIRING TABULATION

ORIGIN	DESTINATION	DESIGNATIONS	WIRE LENGTH
* J05-01	J06-12	A000 TO A001	3 INCHES
* L04-06	J09-12	A002 TO V205	6 1/2 INCHES
* J05-02	J09-12	A000 TO V205	3 1/2 INCHES
* J05-03	I03-12	A000 TO N009	3 INCHES
I02-12	I03-12	A101 TO N009	1 1/2 INCHES
* J05-04	H05-06	A000 TO A201	7 INCHES
H05-06	H12-06	A201 TO N109	4 INCHES
* J06-01	J06-2	A001 TO J042	5 1/2 INCHES
J06-01	J05-06	A001 TO A000	2 INCHES
* J06-02	J07-12	A001 TO A003	3 INCHES
J07-12	J09-11	A003 TO V205	2 INCHES
* J06-03	L01-06	A001 TO N108	8 INCHES
* J06-04	GNDE	A001 TO GNDE	52 INCHES
* L04-01	J07-11	A002 TO A003	6 INCHES
* L04-02	J06-11	A002 TO A001	6 INCHES
J06-11	J08-12	A001 TO N300	2 INCHES
* J07-01	L04-05	A003 TO A002	8 INCHES
* J07-02	J08-11	A003 TO N300	2 1/2 INCHES
J07-02	J05-05	A003 TO A000	2 INCHES
* J07-03	GNDE	A003 TO GNDE	52 INCHES

Figure 4-7
Sample of wiring tabulation

5. Radar Conversion Unit

The system must perform the two separate functions previously described in Chapter 3, i.e., (a) that of direct display of unprocessed video on a digital raster on a display tube, and (b) that of making available to the computer the digital information on a radar return if it is a possible target.

The requirement of a real time radar display places a restriction on the use of the display for computer generated information. The portion of time between start of sweep and the maximum range to be displayed must generate a signal to lock out any memory references to the display. As a result of this restriction, the system has been designed to include two separate display tubes so that one is always available for computer generated display information. The normal display information in the memory is directed to the designated display tube. The tubes are designated "0" for left and "1" for right for purposes of coding command. The choice of which tube is to present the display is controlled by the use of the tube designator bit in the coding structure which will be discussed later. This "tube bit" controls the intensity grid of the designated tube by enabling the "unblank circuitry" to turn on the electron beam. Also, it sets the condition which routes the display deflection signals to the designated tube. When raw video information is desired, the range switch is placed to the appropriate range. The receipt of a "train bit" from the radar sets a flip-flop whose output is used to remove control of tube "0" from the internally generated display information (see Figure 4-1). The

"set" output of the flip-flop "enables" the X and Y digital radar counters to input to the position registers of the digital to analog converters. The "set" output also "disables" the output of the computer generated display information, even though tube "O" may be designated to display some information while in the radar mode. When the designated maximum range has been reached, a signal is generated which "resets" the flip-flop. Thus, the internal display information can now be displayed on tube "O" until the next "Main bang".

The range switch settings are shown in Figure 5-1 along with the time required by the radar to display each beam. This is based on the propagation rate of radar signals being 12.35 microseconds per range mile. The radar characteristics of the undesignated radars to be used with the system are shown in Figure 5-2. The remainder of the table in Figure 5-1 is a listing of the proportion of time remaining for inserting computer generated displays to the total amount of time available. This information should be used when writing system programs to superimpose target information over a radar display. For example, if using the SR3-3 with the pulse repetition frequency set to 500 cycles per second and the range switch set to 64 miles, the availability of tube "O" to the generated display is 60.4% of the time. This indicates that the information should be written into the memory at two places to insure that it will be displayed. This technique of time sharing limits the amount of information that can be superimposed on the longer ranges. The SR3-26 places a slightly more stringent set of re-

Wave Switch Setting in lines	Radar Dis- play time Requirements in micro- seconds	Ratio of Time Available for Display			
		S P S - 8		50-14	50-15
		1:1	1:1	1:1	1:1
	40.5	.05	.75	.002	.005
8	19	.001	.000	.000	.005
16	198	.002	.001	.000	.005
32	196	.004	.002	.000	.005
64	732	.308	.000	.000	.005
128	1000		.000	.000	.005
256	1000			.000	.005

Figure 5-1

Comparison Table of Radar Display Requirements as a function of Wave Switch Setting

	<u>3-6</u>	<u>7-10</u>	<u>11-15</u>
Horizontal Beam Width (in degrees)	.5	3	.5
Horizontal Rotation Rate of Antenna (in revolutions per minute)	5 to 1	1 to 10	1 to 10
Vertical Beam Width (in degrees)	.0	.0	1.1
Azimuth Information Available	1:1 Speed Synchro	1:1 Speed Synchro	1:1 Speed & 10:1 Speed Synchro
Peak Power (in kilowatts)	50	500	500
Pulse Width (in microseconds)	4	4	4 or 2
Pulse Repetition Frequency (in cycles per second)	150	100	100 or 150
Expected Range (in miles for 1 square meter target)	20	22	20

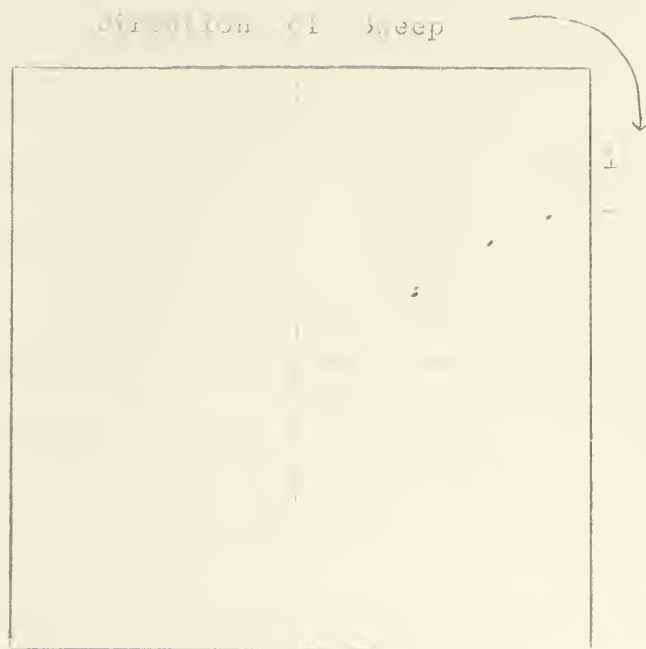
Figure 3-2
Characteristics of Radars to be Used in the System

requirements on the display for time sorting than any of the unclassified radars.

The method of generating the radar sweep requires accurate azimuth information in the form of a shaft position from the radar. This shaft motion drives a digital shaft position encoder whose outputs are sine ϕ and cosine ϕ . The outputs have an accuracy of ten magnitude bits plus a sign bit. These quantized values are then "multiplied" by a series of range pulses in such a manner that counters being driven by the multipliers hold the results $R(\text{sine } \phi) = Y$, and $R(\text{cosine } \phi) = X$. When the range counter reaches its maximum value as determined by the range switch, the range counter is cleared, and the X and Y counters are then disconnected from the digital analog converters by the "enable radar" flip-flop previously described.

This technique then describes a radar display raster of the form shown in Figure 5-3. There are 2,048 separate "bins" in X and in Y corresponding to the 11 bits. This gives a possible accuracy of $\pm 1/4$ nautical mile on the 250 mile range with possible accuracies increasing to ± 7.9 yards on the four mile range. The actual accuracy of the video display without a video processor incorporated to use only the centroid of the radar return is mainly limited by the pulse width of the radar used. The pulse widths range from one to four microseconds (see Figure 5-2) with a resulting possible error of approximately $\pm 1/12$ mile to $\pm 1/5$ mile.

The heart of this system is the range counter and the oscillator driving the counter. The clock frequency required to obtain



The waveforms of successive sweeps 1 and 2 in the above raster are shown below.

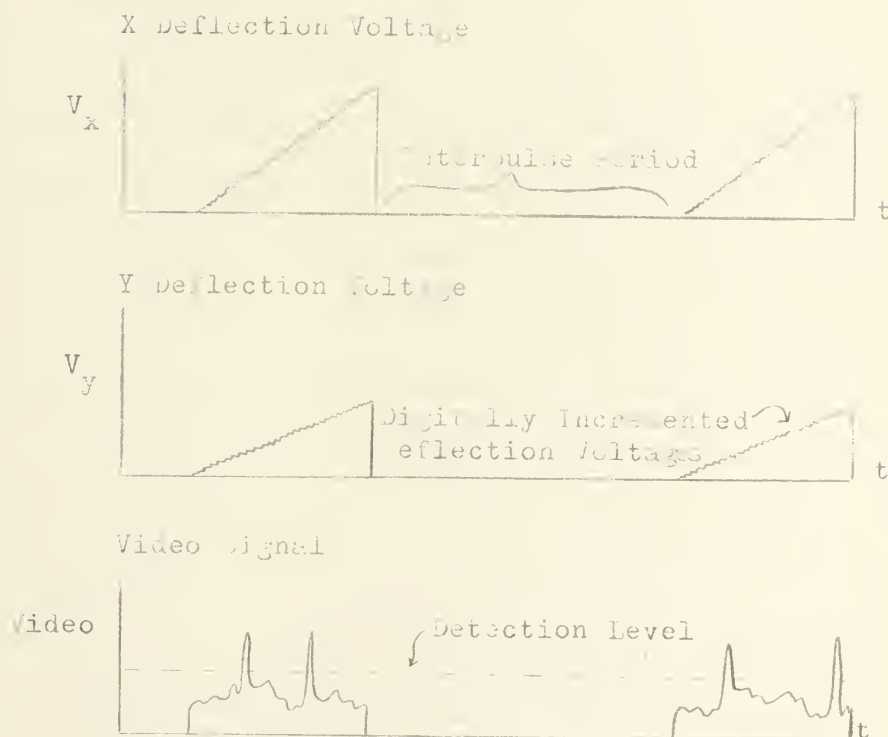


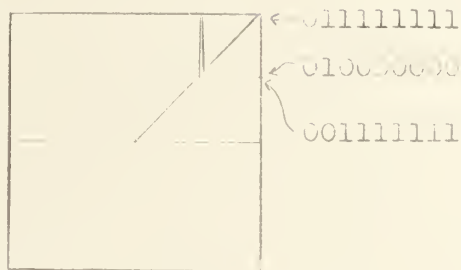
Figure 5-5 Example of the Digital Raster Produced by the RDR-1 can

the accuracies needed is 20.72 m. The Range Switch then enables different bit positions of the counter to trigger the rate multiplier which results in full scale deflections for the chosen range. The radar section of the logic is the unit that determined the need for the new series of fast cards discussed in Chapter 4. The switching times of these logic cards were required to be much faster to reduce spikes in the radar video raster caused by the carry pulse in the counters when the most significant bit changes. (See Figure 5-4) These spikes (or "blivets") should be reduced in width enough to be insignificant by the fast cards.

The requirement of 11 bits of accuracy for the azimuth information requires accuracy to 0.176 degrees. The azimuth information available from the radars is in the form of 60 cycles per second synchro signals. The SP3-8 and SP3-26 have two-speed synchro systems which have an accuracy well within the 11 bits specified by the encoder. The SP3-6 and SP3-12 have only a one-speed synchro system which could have a maximum accuracy of about 0.3 degrees from the components. It is evident then that the available accuracy of bearing information is not quite precise enough for the system requirements. One other problem in this system is that the torque and inertia loads of the shaft position encoder require a high gain servo-system to drive the encoder. In order to furnish the maximum accuracy at suitable power levels to the encoder for each of the radar inputs, it was necessary to convert the individual radar synchro outputs to a single speed, high accuracy synchro output from the radar switch panel. The converter to be used for

The condition exists when a digital increase of one increment in the lowest order bit position causes a carry bit in the higher order bit positions. For example: For a change of the Y counter from 01111111 to 01000000, two possibilities may occur if the circuits concerned have a large difference in rise times.

1. The carry bits may be too fast resulting in the value of 01111111 for an instant.



2. The carry bits may be too slow resulting in the value of 00000000 for an instant.

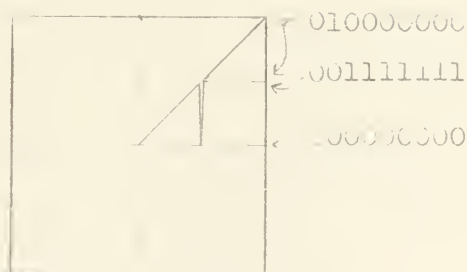


Figure 9-4
Formation of "blivets"

this is a "synchro amplifier". The unit is a standard Navy Supply servo system which accepts one or two speed synchro information and furnishes an accurate one speed synchro output. The output is specified to be a 400 cycle synchro signal for the long cable run from the Radar Laboratory to the Digital Control and Automation Laboratory. A commercial high gain servo system is to be purchased for driving the encoder unit in the DD-65.

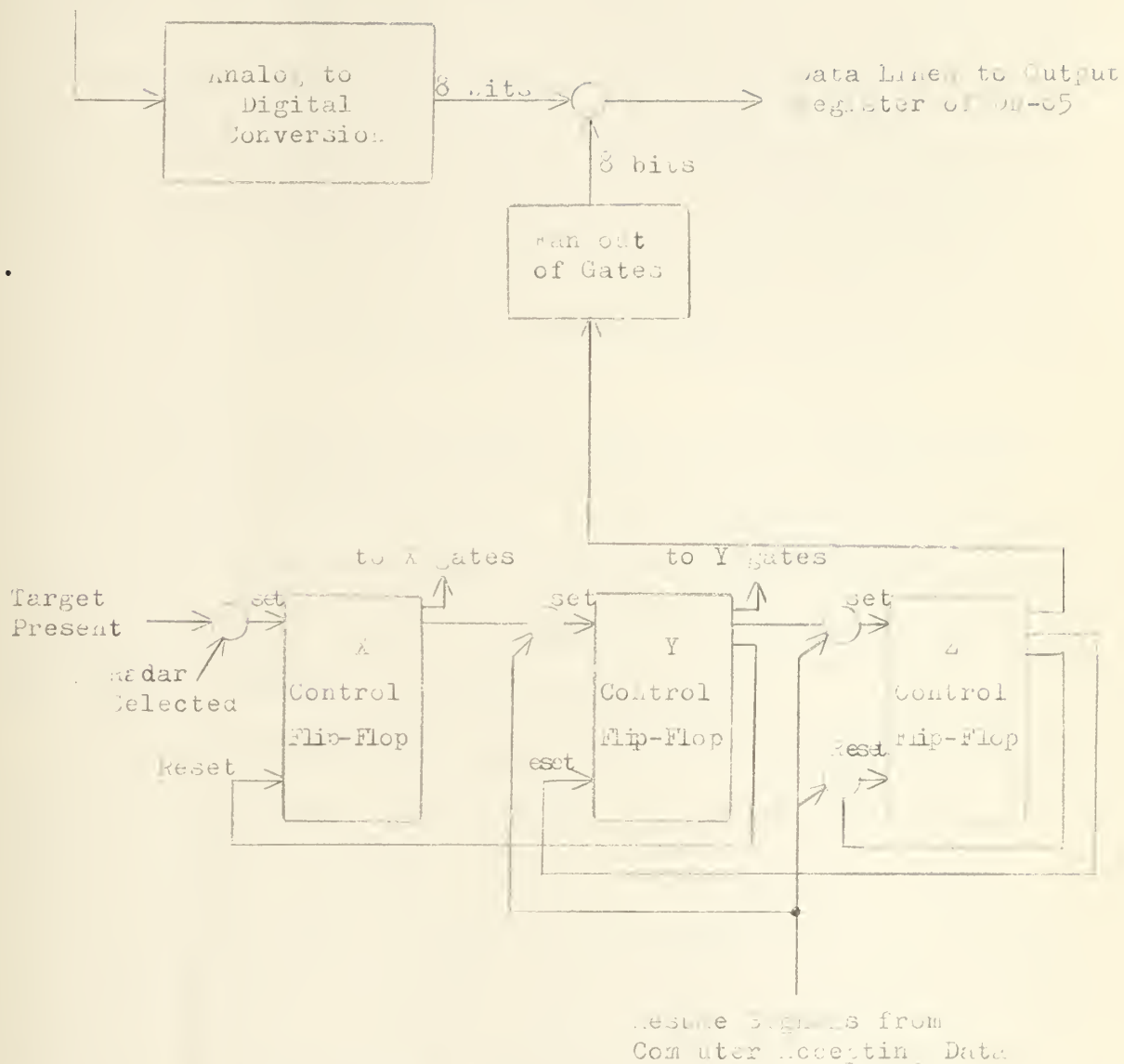
The remaining requirement that the digital radar information be made available to the computer has been implemented by gating the 11 bits of X and 11 bits of Y to storage registers upon receipt of a signal signifying the presence of a possible target. This signal will be generated from raw video by an automatic detector which is designed to trigger when certain conditions are met, such as amplitude, slope of signal envelope, or combinations of time and amplitude. The study of optimum auto-detection units is to be one of the primary uses of this system. The detection units are to be fabricated on standard computer cards and locations for these circuits have been left in the operator's console of the DD-65. One type of detector has been designed and built by D. R. Briggs. It is a threshold detector with a voltage variable false alarm rate. This unit will be used on initial tests and is documented in a separate report /21/.

In the system design it was assumed that either the 160 or 1604 could be called on to process the radar data; so the X and Y registers were designed to be callable separately by the computers instead of packing them into a 22-bit word. This allows the 16

with its 12-bit word structure to handle the processing job without excessive shifting of bits. The request by the computer for radar information sets a step counter which will sequence the X and then the Y information in a two-word group. The computer program must be tailored to this grouping by using a standard block input coding.

Provision has been left for extending the step counter to a three-word radar sequence. This was done to allow a third word, containing some measure of elevation angle or height information, to be sent to the computer for processing when using the SP3-26 or SP3-6. The output register of the DD-65 has eight bits set aside for this purpose. The implementation of this will entail an analog to digital conversion of the raw data into eight bits of digital information and provide a gate controlled by the third count of the step counter to enable the lines to the output register (see Figure 5-5).

Analogue Representation
of Beam Elevation
at Time of Target



Present logic includes only the X and Y control flip-flops.

NOTE: Set side of flip-flop is upper side; reset side of flip-flop is lower side.

Figure 5-5
necessary logic for Addition of eight Information

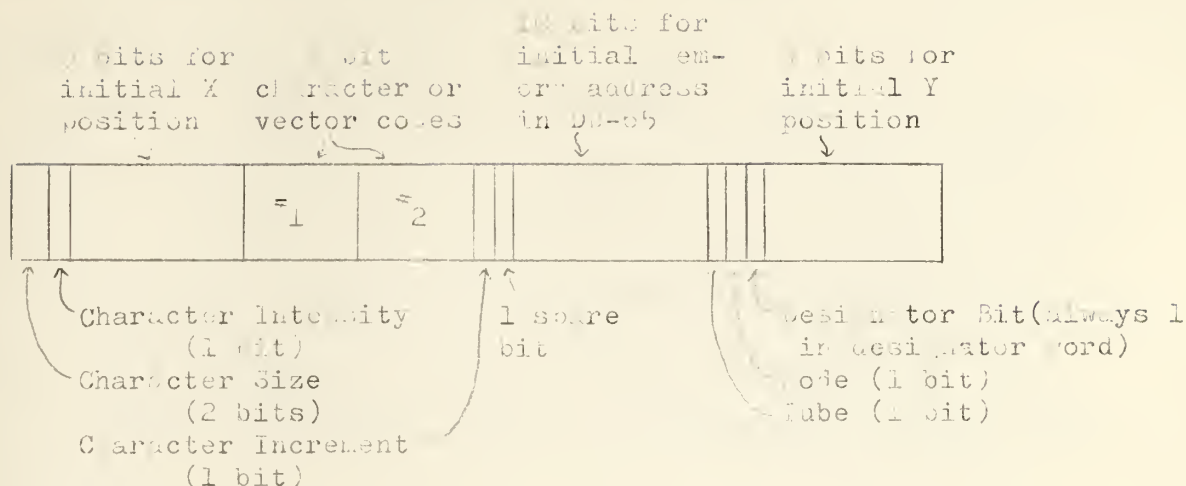
6. Design of Character and Vector Generators

The display of the actual characters and vectors is performed by cycling through the self-contained memory in the MD-05. This memory size is 1024×24 . Therefore, in order to fill the memory with information, 512 words of 48 bits each would be required from the Control Data Corporation 1604 or 2, 48 words of 12 bits each would be required from the Control Data Corporation 160. Any updating of information from the computers to the MD-05 breaks the display cycle, but saves the address of the next display word, and continues from the break address after the new information is read into the memory.

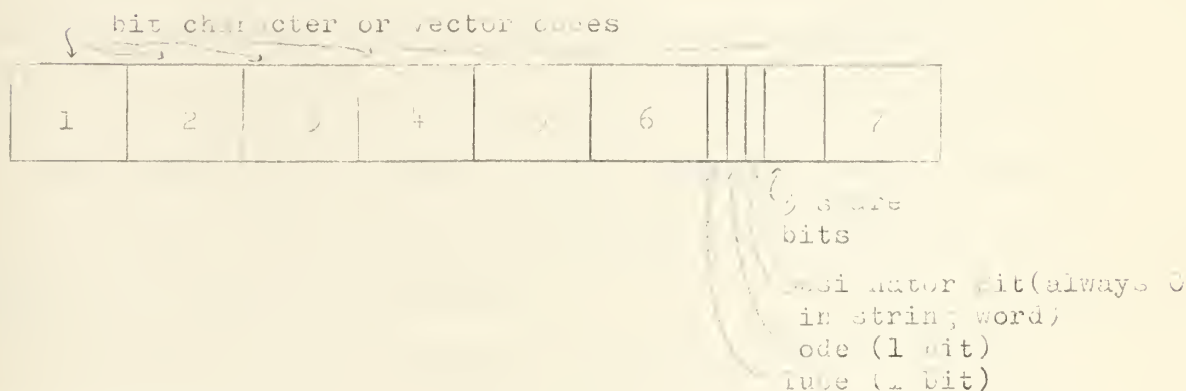
The basic length of the words needed by the decoding logic is 48 bits. This requirement is dictated by the fact that the number of bits needed for control information, position, and address are more than the 24 bits of the memory word. This then limits the total possible number of display words to 512.

As was mentioned previously, the formation of the characters or vectors are grouped into "strings". The first word of each string is called a "designator word". (see Figure 3-1) This furnishes the control information to the decoding logic to prepare for displaying the information. Two characters or vectors can also be packed into the "designator word" to provide fast updating of a moving symbol. All following words up to the next "designator word" are considered to be string words. They can have up to seven characters or vectors packed into each word. The reason for using only seven of the eight possible symbols is the need to be able to

MESSAGE WORD (1-100 words or -10 words)



MESSAGE STRING WORDS



CONTROL CODES:

Mode: 0 - character (enables logic to decode the character information codes)

1 - Vector mode (enables logic to decode the vector information)

Tube: 0 - Display the stored information on left tube

1 - Display the stored information on right tube

X and Y positional information is formed by an eight-bit "absolute" magnitude code with a sign bit added to indicate direction from the center of the tube (0 sign bit is positive and 1 is negative).

Initial memory address of 00-05 must be specified for each string by a 10-bit address code. The storage of consecutive words is incremented within the logic.

Figure C-1 Programmed Information for String Words

uniquely recognize the designator bit "D". Thus, the "D" bit must remain "0" in all string words.

In order to make corrections or update any part of a string, the whole corrected string must be read into the display memory. This is due to the incremental mechanization of the address counter. Only the designator word contains an address reference for the memory. Once a string of display words has been set up to read into the memory, the address counter is incremented as each 24 bits is accepted.

The designator word also contains the initial positioning information for the string. The initial position of the string is specified by nine bits of X and nine bits of Y. This allows a position to be selected to within 1/512 of the usable scope face. The usable portion of a 12-inch diameter tube is a square raster of about 0.5 inches. This allows the position of any symbols to be designated to within 0.0165 inches.

The choice of tube to display the information and the mode (i.e., choice of whether the information is a character or vector string) must be repeated in each word of the string. The appropriate coding for these are shown in Figure C-1.

The vector mode and the character incrementing portion of the character mode use the same logical packages. These are a pair of nine bit position counters. The X and Y position counters are initially set to the position specified in the designator word for a string. The outputs of these counters drive the position registers of the digital-analog converters for the display tubes (see Fig-

ure 4-1). The counters are designed so that the contents may be counted up or down or not incremented depending on the control signals generated in the decoding logic. Thus, the amount and direction of beam movement is determined by the individual mode decoding circuits.

The vector mode requires only initial position information from the designator word. The formation of a line is started by unblanking the beam and then moving it in direction and distance as specified by a six-bit vector code. The beam is then "blanked" while the next six-bit vector code is brought into the decode logic. The sequence is then repeated until the next designator word is encountered. This technique produces a line by starting each new segment from the end point of the last (see Figure 4-2). The blank words between the end of any information and the next designator word causes no problem as the "0" code in either the vector or character mode does not unblank the beam even though the position counters may be incrementing.

The vector decode logic separates the six-bit code into a three-bit direction code, a two-bit size code, and an "unblank" bit. The direction code allows for eight possible directions which corresponds to 45° increments in direction. The size code allows for four possible segment lengths. The unblank bit can be used to form dashed lines by allowing the beam to be blanked while still following a prescribed vector path. The vector codes are shown in Figure 6-3. The direction code determines the operation of the X and Y position counters, i.e., whether to count up, count down or

In order to specify the location of an enemy installation on a military map, the following symbol is used:



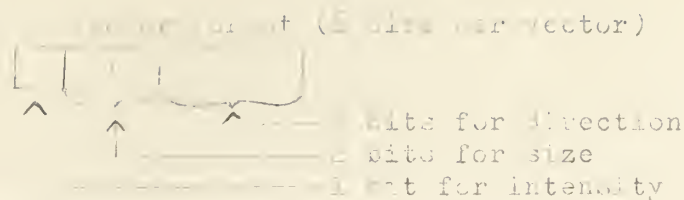
To include this symbol on a map generated by the D-5, the following trace could be generated:



The sequence of necessary vector codes (see Figure 6-1) to form the above symbol is:

- | | |
|------------------------|-------------|
| | (1) 110000 |
| | (2) 110010 |
| | (3) 110111 |
| | (4) 110010 |
| | (5) 110000 |
| | (6) 000011 |
| | (7) 100110 |
| NOTE: The starting | (8) 000110 |
| point location must be | (9) 100010 |
| given in the designa- | (10) 000111 |
| tor word. | (11) 110111 |

Figure 6-2 Example of the Trace Produced by Vectors



Intensity Information

Code	Interpretation
0	0 deflection of the beam
1	normal intensity

Size Information

Code	Interpretation
00	X and/or Y coordinate deflection is 1/128 of full scale deflection
01	X and/or Y coordinate deflection is 1/64 of full scale deflection
10	X and/or Y coordinate deflection is 1/32 of full scale deflection
11	X and/or Y coordinate deflection is 1/16 of full scale deflection

Direction Information

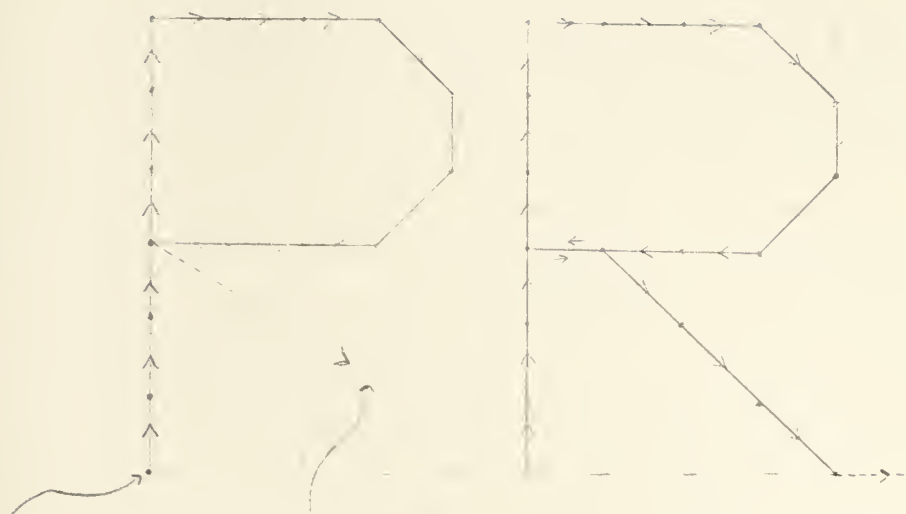
Code	Interpretation
000	Vector is drawn at an angle of 0° from starting point
001	Vector is drawn at an angle of 45° from starting point
010	Vector is drawn at an angle of 90° from starting point
011	Vector is drawn at an angle of 135° from starting point
100	Vector is drawn at an angle of 180° from starting point
101	Vector is drawn at an angle of -135° from starting point
110	Vector is drawn at an angle of -90° from starting point
111	Vector is drawn at an angle of -45° from starting point

Figure 6-3
regression Information for Coding Vectors

not count. The length code determines when to stop incrementing the counters. The incrementing rate is 0.4 microseconds per pulse, and the number of counts must increase in proportion with the line length. The longest line length was included for the purpose of economical drawing of ordinates. One line, the length of the digital raster, can be packed into a string of two words. It is felt that the smallest increment will allow special symbols to be made up from coded vector strings without being incompatible with the normal character sizes.

The character decode logic is considered to be proprietary information by Data Display, Incorporated. The general technique is one of micro-positioning the beam in relation to a reference X, Y position on a 5 x 7 matrix. The logic is entirely designed from the basic inverter logic cards. The characters are formed by moving the beam and turning it on and off under a clock control whose pulses occur every 0.2 microseconds. The character rate is determined by the number of increments needed to trace the most complex character. For the symbol selection of the 00-05 the number of increments required is 55 pulses. This sets the time for display of one character at 0.0 microseconds. This time includes the incrementing of the reference position to the next character location (see figure 6-4).

In addition to the initializing information required in the designator word by both the vector and character modes, the character mode requires some additional information on size and incrementing. A convenience intensity control bit is included to



XY starting
point contained
in designator
word

are planned for movement
to next starting point

formation is on a 5 x 7 matrix with spacing generated by the
matrix size being slightly smaller than the incrementing reflection.

NOTE: The incrementing information is contained in the designator
word.

Figure 3-4
Example of the Trace Produced by Characters

allow a digitized image to be displayed on a screen for an analysis of superimposing data over a trace record or radar display. The format is shown in Figure 4-1. The bit pattern of these information bits sets flip-flops which control the increment to be added to the current string. The size selection is limited to only three out of a possible four as no need is seen for the large character. The character size has a direct relation with the position increment length. As the vectors and characters use the same position counters, the character sizes were adopted to the increment lengths designated for vector lengths. The various codes for character control are shown in Figure 4-5. The normal character sizes are the 32 or 64 per display width. The small size was incorporated to allow for possible future photography techniques which could allow large quantities of printed text to be efficiently recorded for later projection. The direction of incrementing characters within a string is normally to be left to right as in a printed page, but for possible recording of graphs or charts, a down increment can be included. This is easily incorporated as the negative value can be added into the minus side of the Y counter for strings more complex than required for plotting, only into the plus side of the X counter.

Size Information (2 bits)

<u>Code</u>	<u>Interpretation</u>
00	Character size is 1/25 of full scale deflection
01	Character size is 1/4 of full scale deflection
10	Character size is 1/2 of full scale deflection

Incrementing Information (1 bit)

<u>Code</u>	<u>Interpretation</u>
0	Successive characters are incremented to the right
1	Successive characters are incremented vertically downward

Intensity Information (1 bit)

<u>Code</u>	<u>Interpretation</u>
0	Normal intensity
1	Brighter than normal intensity

NOTE: The usage of these character control codes is shown in Figure 3-1.

Figure 3-5
Character Control Codes

7. Design of the Input, Output and Control Functions

In order to commit the requirements of Chapter 3 to hardware, a suitable set of rules in the form of logical circuitry must be designed to allow for the establishment of communications between the various units of the system, and the collection and transfer of data between these units.

The establishment of communications with the computers is accomplished within the standard structure of sense and select commands of the Control Data Corporation 160 and 1604. These commands and the control signals have been documented in the company manuals /17, 18/ and have been included as Appendix 2 to this thesis. All reference to command structures will be made in "octal" notation instead of the actual binary notation. The requirement that the computers can be selectively locked out of the system places an additional restriction on the decode functions. It was decided that in the individual computer operation modes (i.e., 160 only, or 1604 only), the select codes for the other computer would be uniquely locked out. In the combined operation mode ("both"), the restrictions were lifted, and the computers can cross select to control the flow of information. For example, it is possible for the 160 to select an interrupt condition for the 1604 in this mode. The only arbitrary decision concerns the flow of manual input (i.e., keyboards, track ball and range switch). In the "both" mode all manual input selects are gated so that the data is input to the 1604.

The request for information or action by a computer is indicated by a 12-bit external function code being transmitted to all

peripheral equipment along with any control signal over their separate lines. From a study of all codes assigned to actual or proposed peripheral equipment for the computers, it was found that the 7XXX series of codes was not designated. This 7XXX series was chosen as the unique code series of the DD-65.

In order to continue further into the design of the control structure of the DD-65, it next became necessary to precisely define the various inputs and outputs and their inter-relationships.

The structure of the display words to be transferred from the computers to the DD-65 has been described in Chapter 6. These are the only data channel inputs to the system from the computers. The transfer of the "strings" of display information is to be by normal computer output blocks. The DD-65 must, then, have the provision for recognizing commands from the computers, to select this transfer, and to set up a "ready - resume" system of signals to control the input of the block of information. These two transfer channels have no restrictions set on them by other data codes of the system, but they should be mutually exclusive.

The digitized radar information is a sequence of words from the radar channel to one of three possible terminal equipments, i.e., the 16-4, the 160 or the auxiliary channel. The sequence is controlled by a counter which successively gates in the 11 bits of X and the 11 bits of Y, and has provision for extending this to gate in eight bits of height information. These eight bits of elevation allow an angular resolution of about 1/4 degree. This sequence is triggered by an externally produced target pulse which

is manufactured from the video of the detection circuit. This input entails two levels of selection to be made by the select code used. These are: (a) the choice of one out of three possible terminations for the information and (b) the selection of accepting the radar information exclusive of all other inputs to the DD-65 except from the computers.

The group of manual inputs from the operator's console can only be directed to the computer assigned by the mode switch (as described in this section). This places the requirement for only a single input selection on the select code. The selection is to be exclusive of all other normal input selects.

There is one other unique input necessary from the DD-65 to the Control Data Corporation 160. This is the response to a "status request". This response should be selectable to the exclusion of all other inputs when the program on the 160 is checking for the occurrence of conditions at the DD-65. The response is coded into a one out of twelve response. In this way, if more than one recognizable condition has occurred, the response will include them, and it is up to the 160 program to check for the conditions. The "status response" selection is disabled when in the "1604 only" mode. Note that the 1604 operates the sensing of conditions of the peripheral equipment in a different manner. It uses a separate control signal to denote that the condition has been met.

To expand on the manual inputs, the following separate pieces of information are generated:

- a. X track ball 9 bits

- d. Y trace ball 8 bits
- e. overlay 8 bits
- f. range switch 3 bits
- g. symbol keyboard (number 1) 4 bits
- h. Control keyboard (number 2) 8 bits

The X and Y trace ball information has been made separately selectable to keep the 60-65 output register to less than 12 bits so that the same output register and usage rules may be used by both the 180 and 1804. The overlay and the control keyboard have been combined into a nine-bit output, as the method of interpreting the commands of the control keyboard is dependent on the overlay which should control the program package. The range switch and the symbol keyboard are treated independently.

The use of light feedbacks to the console operator (in conjunction with the control keyboard) dictated the need for additional select code requirements. These select codes are used to turn on or off any of the lights as occurred with the control keyboard. There is no restriction on the use of these selects as they have no inter-action with the inputs or outputs.

One other mode of operation to be incorporated is to be using the interrupt feature available on the Control Data Corporation 1804. These selections need not be unique or exclusive as the portion of the program entered when an interrupt occurs can be made to sense which of the selected interrupts has occurred.

A general diagram of the control function circuits is shown in Figure 7-1. A more detailed breakdown is given in Figure 8-1.

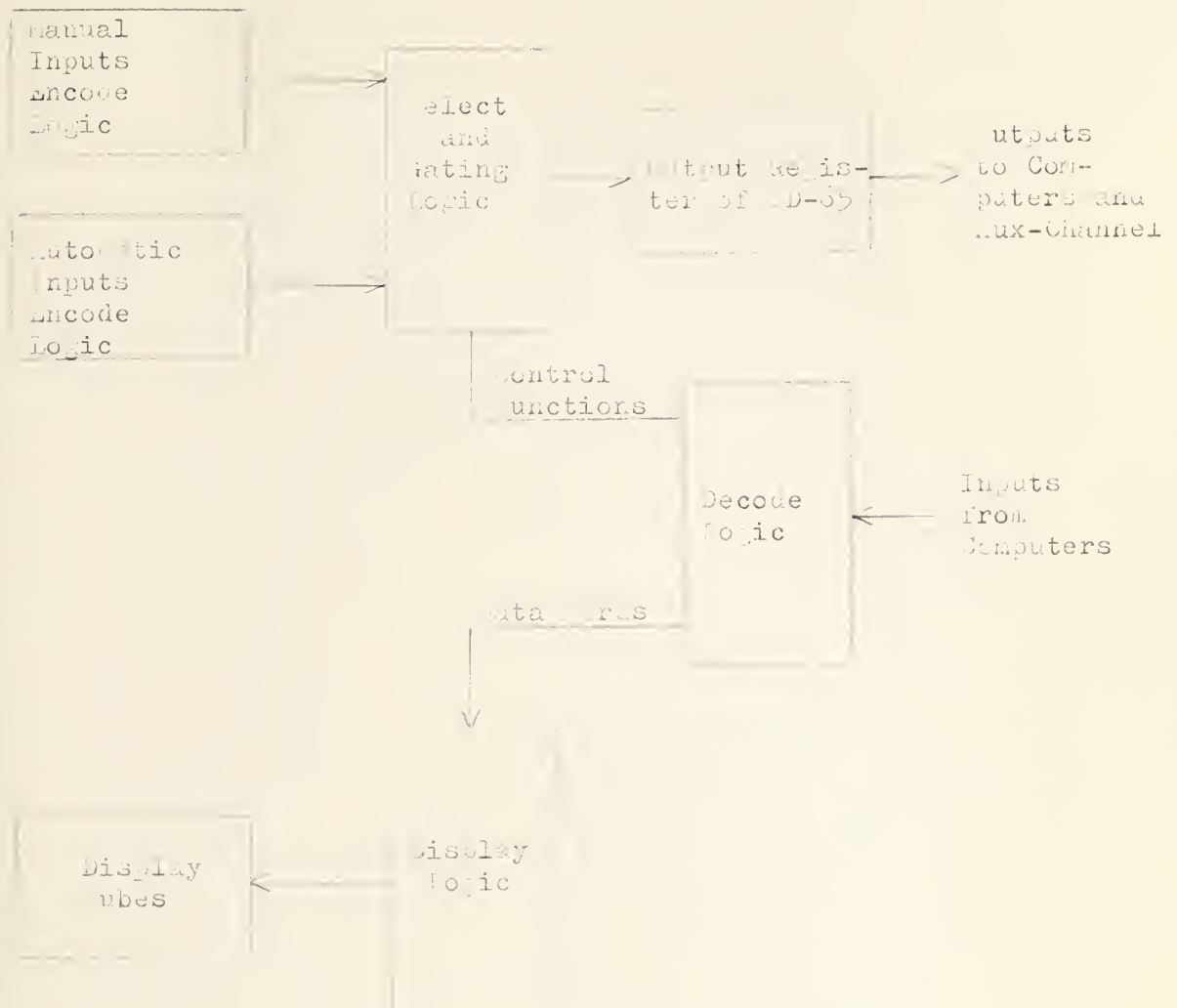


Figure 7-1
General Block Diagram of Control Functions

The manual in which this set is described in detail is intended to precisely define the necessary commands. The keyboard code set uses a maximum of 4 possible codes. This is specified by the allocation of six bits in the 8-bit word. In order to determine the necessary number of symbols needed for verbs and number one (one symbol per verb), a comparison was made of the symbols sets required for various programming languages. This comparison included the assembly programs A8-2 /21/ and A8-1 /22/, the business oriented compiler COBOL /24/, and the algebraic compilers ALGOL /25/, BASIC /26/, and FORTRAN /27/. In addition to the code set, it was also necessary to include certain few editing keys. These are "carriage return", "tab", and "erase". The choice of symbols for the symbols was made using the criteria that at rationalization of the code would be desirable. The coding that evolved is an expansion of the basic "Binary Coded Decimal" (BCD) which is standard in most input and output equipments not having a provision for upper and lower case. The code "0" was not assigned an input symbol, but the key was included on the keyboard so it can act as an alternate space code. This allowed 60 symbols to be assigned to the remaining codes. The final assignment is shown in Figure 7-2. The physical layout of the keyboard was planned to separate the two major functions of its use. A standard typewriter keyboard and a tabular type numeric keyboard were formed by taking the key covers of a different color than the special keys around them. This should allow easier identification of these areas of the keyboard for more efficient usage. The 64-key keyboard was bought as a com-

<u>Symbol</u>	<u>Octal Code</u>	<u>Symbol</u>	<u>Octal Code</u>	<u>Symbol</u>	<u>Octal Code</u>
Ø	10	C	4	.	70
1	01	D	47	↑	55
2	02	E	50	,	28
3	03	F	51	→	35
4	04	G	22	<	72
5	05	H	23	≥	37
6	06	I	24	≠	14
7	07	J	25	=	13
8	10	K	26	/	21
9	11	L	27	k	58
A	61	M	30	+	50
B	62	N	31	-	45
C	63	CR	70	¶	16
D	64	Tab	20	¶	25
E	65	space	20	space	00
F	66	}	52	^	57
G	67	{	75		
H	70	[17		
I	71]	32		
J	41	^	24		
K	42)	74		
L	43	:	15		
M	44	//	55		
N	45	;	77		

Figure 7-2 Symbol Character Codes

lete package. Additional logic was incorporated to make the unit compatible with the "ready - resume" signals of this system. The keyboard layout is shown in Figure 6-5.

The control keyboard (keyboard number two) is a collection of function designators. The proposed usage for them is for calling routines and subroutines for aid in console usage. This keyboard is also closely associated with the overlay and the light feedback features. There are three groupings of switches in this control keyboard (see Figure 6-5). The first group is a 20-switch matrix which is used in conjunction with the overlays. The functions performed by each switch are engraved on the plastic overlay panel which fits around the switches. The computer can illuminate selectively any switch or switches under program control to present a "guided" choice to the operator for his actions. The eight overlays available give a choice of system programs callable from a single library tape. The second group is a ten-switch unit which is also under computer control for light feedback. These are not associated with changeable overlays and are intended to perform functions which are common to all overlays. For instance, one of these keys could be labeled "display trace ball symbol on left trace". The last group is a diamond of four switches which are intended to be used in editing symbols. They can be used to activate routines to move a marker over the face of the displays. This marker can be used to indicate the position for writing or erasing the next character. The movement commanded by these switches is intended to be incremental in nature as opposed to the "continuous"

nature of the two hall. These two keys are not associated with the computer controlled light feedback feature.

The coding of keyboard number two is made up from a diode matrix which was designed to use the minimum number of diodes. The coding of these keys is shown in figure 7-3. The depression of a key in keyboard two sets up a ready condition which is held until the computer samples the lines and releases the register. The overlay code is transmitted along with the control keyboard code when the input from keyboard number two is sampled. The overlay code is generated by the presence or absence of a contact post in the three bit positions of each overlay panel. This allows for changing the overlay code with a change of the overlay, and hence, to be able to change the labels associated with each of the 10 switches in the matrix.

The X and Y trackball generators are nine-bit shift position encoders whose outputs are in "Gray Code" /20/. The outputs are converted to binary code for use in the computer. This coordinate information is always available and need only be selected by the computer to sample the value.

The radar display range switch is an eight-position switch. There are seven selectable ranges and an off position. The codes are shown in figure 7-4. The switch has the dual function of controlling the radar video presentation and providing the computer with a measure of range correlation for making computations on target position. The entire operator's console is shown in figure 8-5.

SWITCH POSITION	DECIMAL CODE	SWITCH POSITION	DECIMAL CODE	SWITCH POSITION	DECIMAL CODE
1-A	01	4-A	31	5-1	61
1-B	02	4-B	32	5-2	62
1-C	03	4-C	33	5-3	63
1-D	04	4-D	34	5-4	64
1-E	05	4-E	35		
2-A	11	5-A	41		
2-B	12	5-B	42		
2-C	13	5-C	43		
2-D	14	5-D	44		
2-E	15	5-E	45		
3-A	21	6-A	51		
3-B	22	6-B	52		
3-C	23	6-C	53		
3-D	24	6-D	54		
3-E	25	6-E	55		

Keyboard - Function Switch Designation

	1	2	3	4	5-1		A	B	C	D	E
A					4	5-2					
B											
C						5-3					
D											
E											

Figure 7-5
Function Switch Codes

Range Position

Decimal Code

Off	0
4 miles	1
8 miles	2
12 miles	3
16 miles	4
20 miles	5
24 miles	6
28 miles	7

Figure 7-4
Range Switch Codes

Now that all input and outputs are defined, it is possible to assign select and sense codes, and design the logic. Two editing functions were added to the sense and interrupt functions. These were the keys 'carriage return' and 'tab' of keyboard one. These were included as special cases of keyboard one for the possibility of processing a word or a group of words on a functional command instead of processing single characters. The sense codes are listed in Figure 7-5. The select codes are listed in Figures 7-6 and 7-7.

All the function codes are in the 7XXX series. The primary decode is done by checking for the coincidence of a 7XXX and one of the external function signals from the computers. In the "both" mode of operation a time shared check is made of the external function lines from the 160 and 1604. The checking rate is rapid enough to return to sample each computer bit in the eight microseconds that the function pulse is present. Once the initial 7XXX is recognized, a pulse is formed which samples the lower nine bits of the code and sets the selected flip-flop (or in the case of a sense code for the 1604, allows an output pulse to be formed conditioned on the sense).

The ability to clear all the select flip-flops has been incorporated using the external clear lines of the computer in control (as selected by the mode switch). In addition to these possibilities, the "clear/start" control for the DD-45 memory will clear all select flip-flops. The overall diagram of the control logic is shown in Figure 8-2.

<u>Sense Condition</u>	<u>1604 Sense Command Codes</u>	<u>160 Sense Response Codes</u>
Keyboard no. 2 hit	7103	1xxx1
Keyboard no. 1 hit	7104	xxxx1
Carriage Return hit	7110	xxx4
Tab hit	7110	xx1x
Radar target present	7140	xx2x
Keyboard no. 2 not hit	7103	
Keyboard no. 1 not hit	7103	
Carriage Return not hit	7111	
Tab not hit	7121	
No radar target	7111	
Keyboard no. 1 selected	7000	xx4x
Radar to ADX selected	7011	x1xx
Radar to 1604 selected	7002	x2xx
Radar to 160 selected	7001	xxxx
DD-05 from 1604 selected	7010	1xxx
DD-05 from 160 selected	7020	2xxx
Keyboard no. 2 selected	7040	4xxx

Figure 7-5
Sense Function Codes

Function	100	1000	10000
Select Track Ball X	7102	7102	XXXXXX
Select Track Ball Y	7104	7104	XXXXYY
Select Range Switch	7110	7110	XXXX
Select Keyboard 2 plus Overlay	7120	7120	XXXXVV
Select Keyboard 1	7140	7140	XXXX
Select Keyboard 2 plus Overlay with Interrupt on Key-hit	7105	7105*	XXXXVVFFrrrr
Select Keyboard 1 with Interrupt with Interrupt on Key-hit	7105	7105*	XXXXXXOrrrrr
Select Keyboard 1 with Interrupt on Carriage Return	7111	7111*	XXXXXX(C.R. Code)
Select Keyboard 1 with Interrupt on Tab	7111	7111*	XXXXXX(Tab Code)
Select Radar Info to 1004 with Interrupt on Receipt of Target Pulse	7141	7141*	XXXXXX XX YYYY (04/100/Future Same)
Select Radar Info to Auxiliary on Receipt of a Target Pulse	7001	7001	Same
Select Radar Info to 1004 on Receipt of a Target Pulse	7102	7102*	Same
Select Radar Info to 100 on Receipt of a Target Pulse	7001*	7001	Same
Select 100 Status Response	7000*	7000	See Figure 7-5 for 100 Status Responses
Select n-word memory Update from 100	7010	7010	None-See Figure 7-1 for Chain Info.
Select n-word memory Update from 100	7020*	7020	None-See Figure 7-1 for Chain Info.

On 100 only - all manual inputs to the 100; on 1000 only or both - all manual inputs to the 1000.

* Disabled selectively on 100 only or 1000 only - see switch position figure - Select Function Codes for Control Functions

Light Code
1504 110

Select Light	1A-On	7202	7202
Select Light	1A-Off	7203	7203
Select Light	1B-On	7204	7204
Select Light	1B-Off	7205	7205
Select Light	1C-On	7210	7210
Select Light	1C-Off	7211	7211
Select Light	1D-On	7220	7220
Select Light	1D-Off	7221	7221
Select Light	1E-On	7240	7240
Select Light	1E-Off	7241	7241
Select Light	2A-On	7302	7302
Select Light	2A-Off	7303	7303
⚡		⚡	⚡
Select Light	0E-Off	7741	7741

Keyboard 2-Light Designation--

A	*	*	*
B	*	*	*
C	*	*	*
D	*	*	*

A	B	C	D	E
*	*	*	*	*
*	*	*	*	*

Figure 7-7
Select Function Codes for Light Feedback

6. System Implementation and Conclusions

The preceeding chapters described the design details of the functions to be performed by the DD-65. The complete block diagrams for the DD-56 are shown in Figures 8-1 and 8-2. The physical design of the unit requires over 1,500 logic circuit cards. In addition to these components, a number of power supplies and the deflection circuits for the display tubes are required. This large number of components, a number of power supplies and the deflection circuits for the display tubes are required. This large number of components prohibited a single cabinet design for the equipment. The digital logic has been placed in a separate cabinet which also contains all the low voltage power supplies for the digital circuits and the data line terminations from the computers. The operator's console contains the manual inputs and the display tubes as well as the high voltage power supplies to control the display tubes. Also incorporated in the operator's console are the digital to analog conversion circuits and the radar video circuits.

The entire system block diagram is shown in Figure 8-3. The pulse amplifier, video amplifier, and video quantizer are designed for implementation on the same size printed circuit cards as are used in the digital circuits. This allows these circuits to be contained within the logic cabinet of the DD-65. The final configuration of the DD-65 led to the proposed placement of the equipment in the Digital Automation and Control Laboratory as shown in Figure 8-4. The installation should be completed by August 1962.

The system, as designed, allows a great deal of programming flexibility and, therefore, a similar flexibility in respect to use of the operator's console. No attempt will be made here to flow-chart or dictate the type of system programs to be used with the DD-65, but a broad overview of possible functions will be undertaken. The discussion will be slanted toward specification of labels for the various overlays and operator keys. See Figure 8-5 for a diagram of entire operator's console.

The basic set of eight overlays could be specified as follows:

- a. Air surveillance and flight following
- b. Air intercept and control
- c. Program composition and de-bugging
- d. Servomechanism design
- e. Network synthesis
- f. Library information retrieval and update
- g. Linear programming package
- h. Statistical analysis package

Additional sets of overlays could be used by merely changing the system library tape in the computing center. These overlays have twenty unique function keys available for use which have the labels associated with them changed each time the overlay is changed.

These labels and, hence, the programmed functions should include only those functions which are not common to all usage overlays.

The individual labels and associated programs can be determined only by actually outlining each overlay program in considerable detail. A few possible functions that could be associated with the

"programming" overlay are the selection of the various languages to be used for coding. These language select keys would set up a format subroutine for accepting "symbol keyboard" information. For instance, the "tab" key would produce character spacing which would be compatible with the format normally used to input the language to the computer. Further "step process" keys could be labeled for the storing of a completed program on a magnetic tape library or for a "trace" mode of running for de-bugging purposes.

Those functions which are common to all overlays are to be controlled by the ten function keys which are associated with light feedbacks, but whose labels are not changed with the overlay change. The possible set of functions to be programmed with these keys are:

- a. Tube "0" display
- b. Tube "1" display
- c. "Display" track ball
- d. "Hook" track ball
- e. "Drop" track ball
- f. Enter data
- g. Delete data
- h. Start process
- i. Stop process
- j. Load library

These functions are tentative, but the set of functions described are common to all the proposed overlays, and the subroutines involved should not take many cells of the memory to implement. The track ball sequence, as proposed, will entail calling for the dis-

play of the track ball on a particular tube, and then the operator can move the displayed "TB" symbol to the desired position by movement of the track ball. The "hook" track ball can then be executed which can have various meanings depending on the usage overlay. Possible uses of "hook" would be to insert a point or symbol at the designated spot on the display or the process could be reversed, and information concerning the point which is designated by the "TB" symbol could be displayed. The "drop" track ball could be executed after either a "display" or "hook". This function command could mean to delete a symbol or point from the display or drop the "TB" symbol and/or the amplifying information called up by the hook. The "Load", "Start", and "Stop" functions are proposed to be associated with the handling of display data within the computer. For instance, to enter a line of data could mean to place it into permanent storage location for processing after the temporary (for display purposes) information has been verified as correct.

The remaining four function keys are to be marked with direction arrows and are proposed to be used to move an editing symbol over the chosen display tube for purposes of locating the position for typing in or erasing information.

The actual operation of a system as proposed would require an overlay to be inserted and a library load executed. The computer, when ready to commence, would light the "start" process light. The operator, upon depressing the "start" process button, causes the computer to drop the selected light and start through the executive program. Upon reaching various points in the programs where infor-

mation is needed from the operator, various lights or groups of lights are selected "on" by the computer. The function labels associated with the lights outline the required action or inputs to be initiated by the operator. In this manner of reply-request-display, the man can thread through the programs in close association with the computer until the operator chooses to stop the process by depressing the "stop" function key.

It is felt that the flexibility in usage of the command console and the speed and packing density of the display information will provide an experimental device for man-computer systems which will not rapidly become obsolescent.

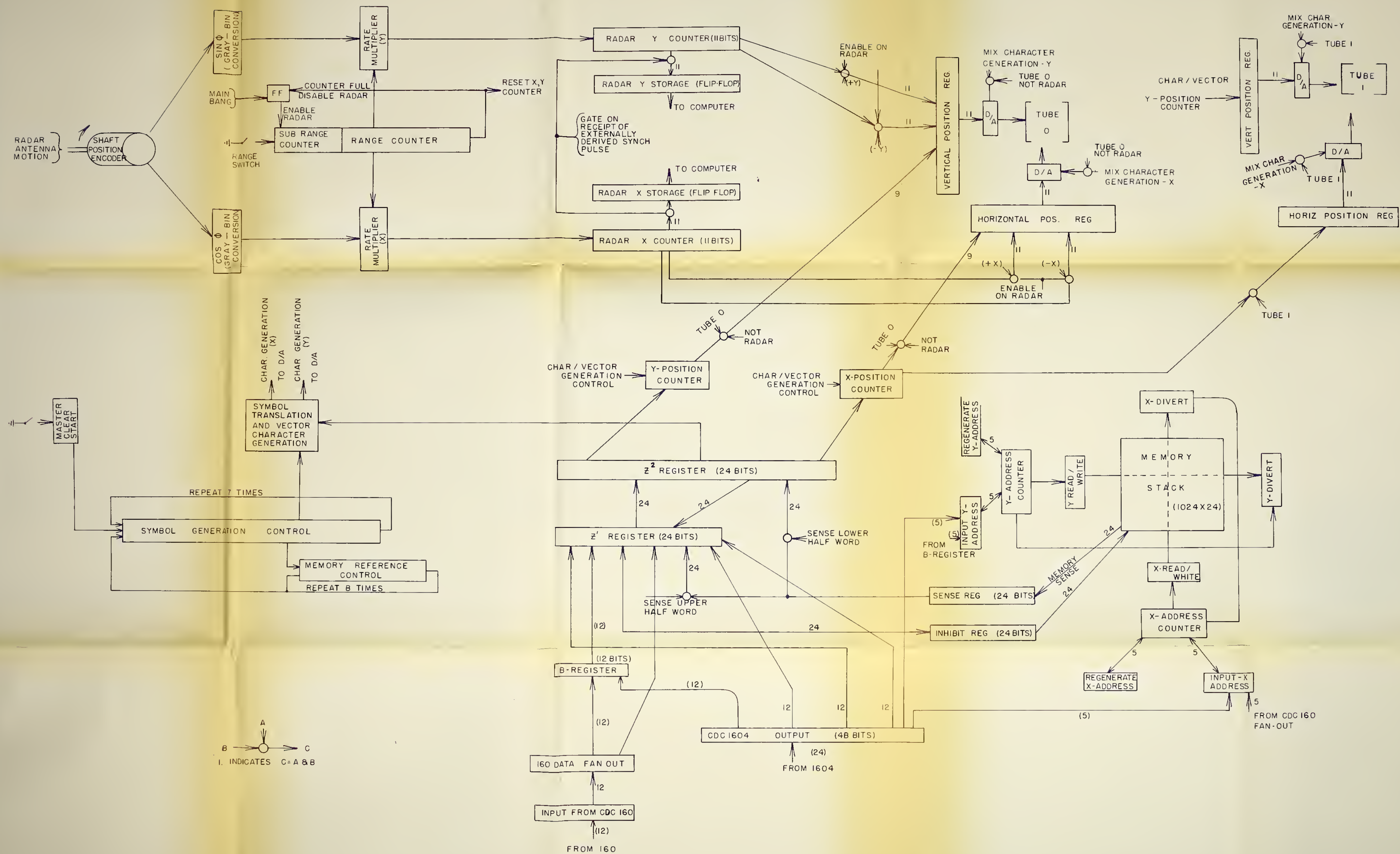


FIG. B-1 BLOCK DIAGRAM OF THE SYMBOL & RADAR
 PAGE 79 GENERATORS & THE MEMORY

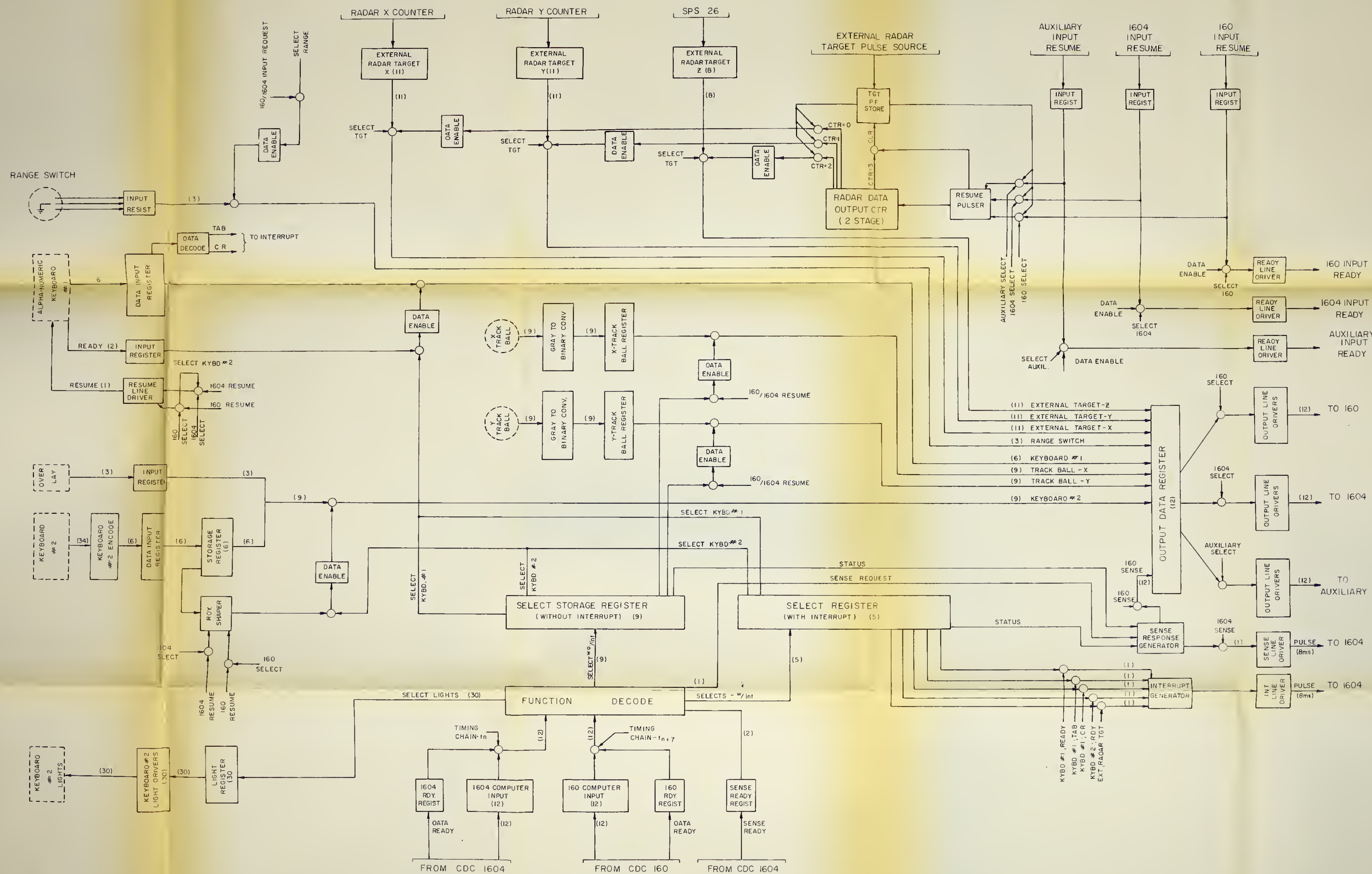
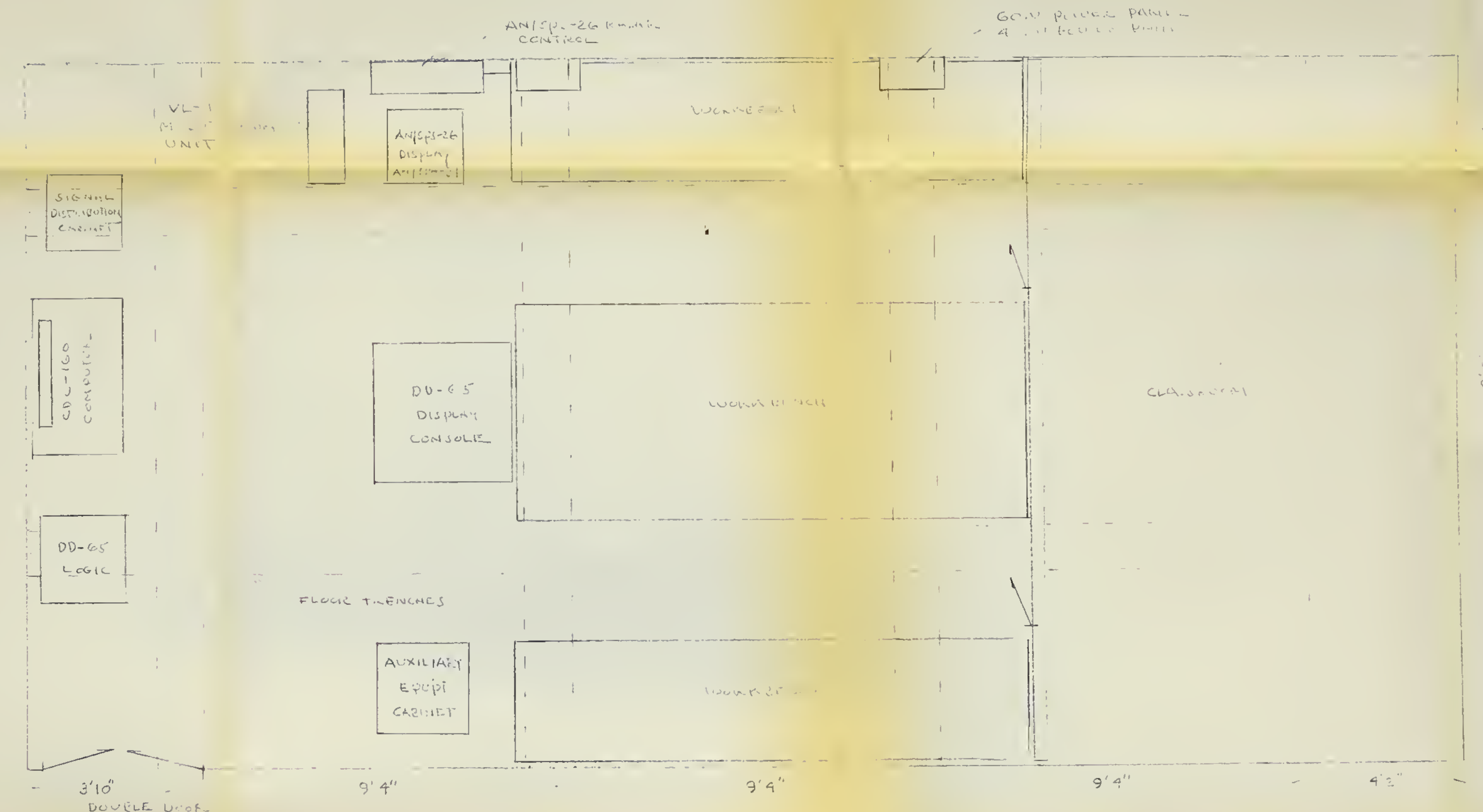


FIG. 8-2 BLOCK DIAGRAM OF THE CONTROL CIRCUITS
PAGE 80

DD 65

LOGIC CABINET: 68" HIGH
41" DEEP
37 3/4" WIDE

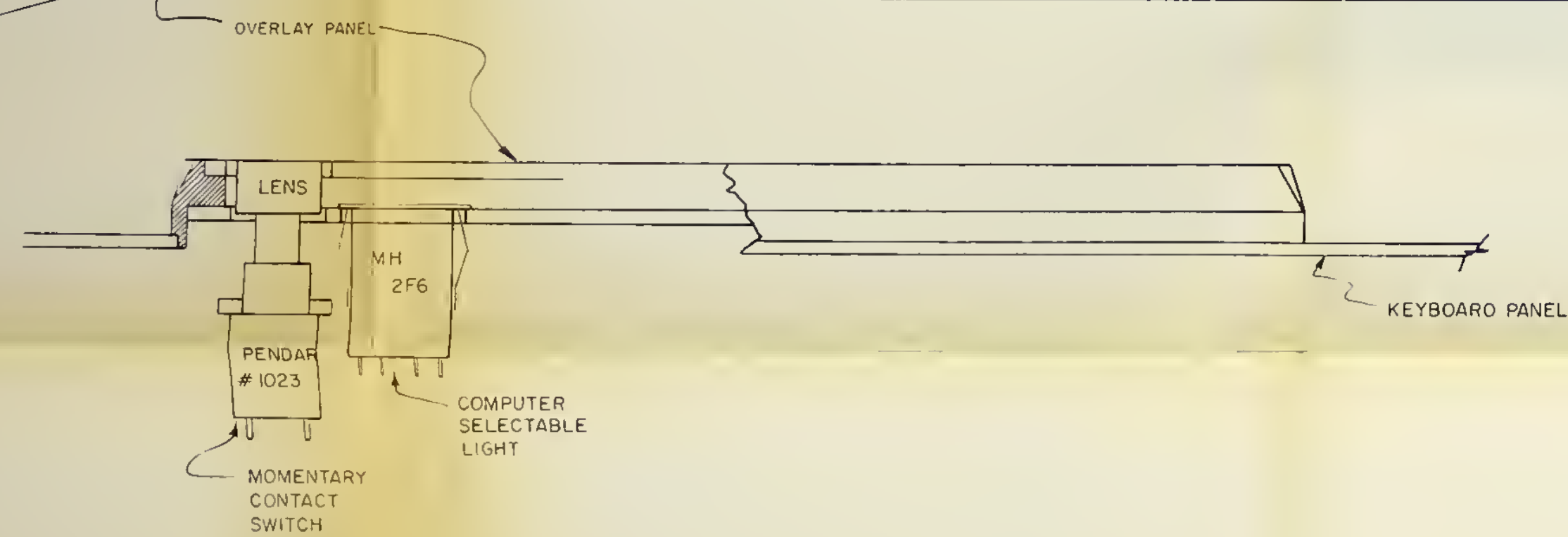
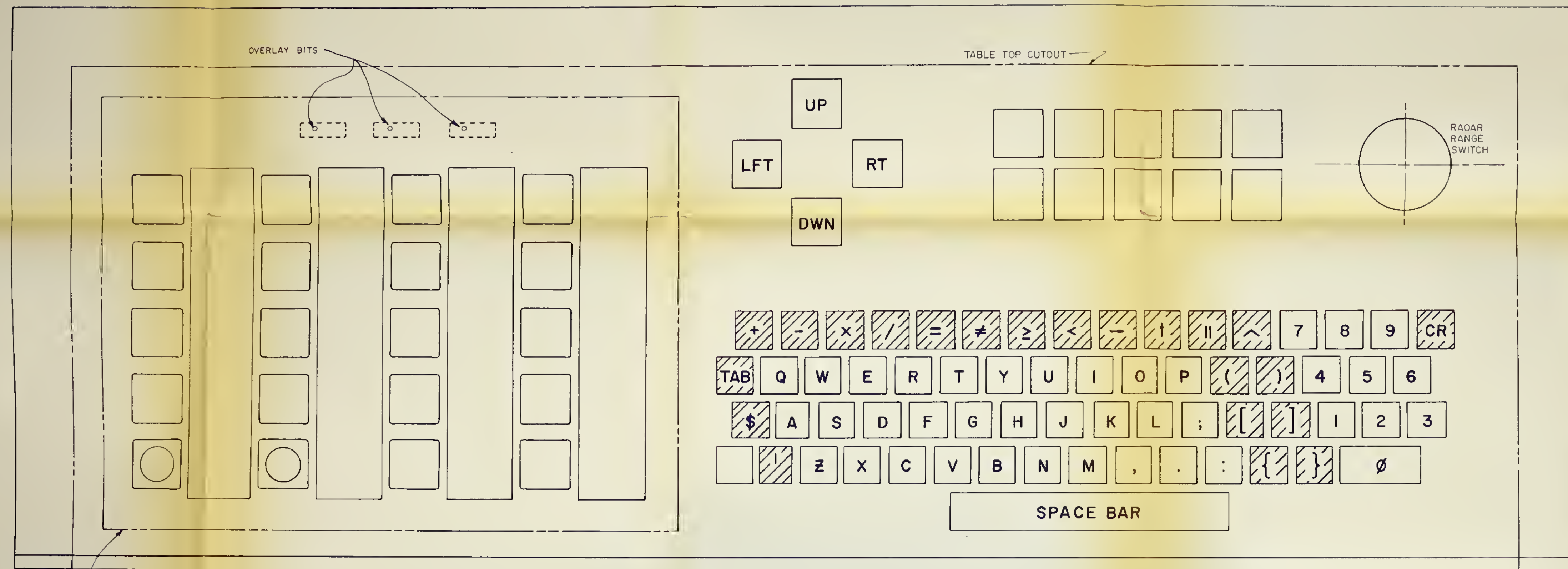
OPERATOR'S
CONSOLE: 49" HIGH
51" DEEP
60" WIDE



PLAN - ROOM 2
BUILDING 10

REF: INDIAN 12ND RM-CE-003

REVISION	DATE	APPD	DESCRIPTION	BY
DES. C. G. L. W. S. H.			Industrial Manager, USN, 12th Naval District	
DWN. L.			ELECTRONICS DEPARTMENT	
CHK. L.			USNAVAL POLYGRAPHIC LAB.	
PROJ. ENG. L.			DIGITAL CONTROL LAB. NO. 1	
BRANCH HD.			FLOOR PLAN 9	
DIVISION HD.			EQUIPMENT LAYOUT	
SCALE:			NO SCALE	
SHEET	2	OF 2	APPROVED	
DATE	APR 1964		FOR INDIAN 12ND	ELECTRONICS ASST.
SATISFACTORY TO			INDMAN 12ND SKETCH NO.	
FOR		USN		
DATE				



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APPENDIX I

DESIGN MECHANIZATION PROGRAM

Description, use and coding of a Control Data Corporation 1604 program for mechanizing portions of the design of digital equipments using Control Data Corporation type logic cards and format.

This appendix is written in standard "Co-op"¹ program description form.

Examples of sample outputs and inputs are shown in Figures 4-4 through 4-7 of this thesis.

¹ "Co-op" is the Control Data Corporation 1604 user group organization.

A. IDENTIFICATION

Title: Card Assignment and Wiring List Assembler for Control
Data Corporation Input file of Equations

Category: Logical Design Aid

Programmer: C. G. Lawson

Date: 30 January 1962

B. PURPOSE

This routine is a composite of two separate functions:

1. It completes a file of equations and assigns card types to each equation for a given set of input equations.
2. It also computes and lists a wiring table if chassis locations for each section are designated.

In order to accomplish the first function, a magnetic tape containing punched card images of the input equations are processed by compiling an input table for the entire set of equations. This table is then searched to make up a list of outputs for each card. The number of inputs and outputs are then counted and logic cards are assigned, based upon the constraints of the family of cards. Certain special card types may be designated in the equation statements by special symbols. The number of cards required are counted during this process, and any erroneous equations are noted. The output at this point is a magnetic tape having the original input equations, each followed by a line containing the card type and a list of output destinations. Also, for any erroneous equations a star is placed in the left column adjacent to the equations. Following the equation file on the tape is a list of the card types

and the total number of each required for the design.

The second part of the program adds to the output tape a wiring tabulation of the intercard wires. In order to make up "wire tabs" the location of each section must be designated. This is done by adding the location information to the punched card for each equation. The program is then run with jump key one set and with an input of a magnetic tape containing the punched card images of the equations and locations. When there is a choice of wiring between points, the program compares lengths and assigns the shortest interconnection possible. The output is now a magnetic tape which contains all of the output lists.

The purpose for separating the program outputs is due to consideration of design procedures. In most cases the file of equations are written from logic diagrams which do not necessarily show all the output wires. The clarity of the diagrams is improved if fewer interconnection lines need be shown. Therefore, the type card cannot always be assigned before finding how many outputs are needed. Also, if the total number of outputs required are more than the legal possible number of outputs, paralleling of signals is necessary. These considerations dictate that the completion of a design be done in two parts. The first part is to find out the card types necessary and to point out any errors in the equations. The location for the sections may now be assigned based upon the knowledge of card types and, also, any corrections may be entered into the input equations by changing the erroneous punched cards. The new inputs will now allow the output of all the desired lists

for wiring, the console.

L. UTIL

1. Calling Sequence:

- a. On biocatal tape at present time
- b. Start location = 5000
- c. Successful completion leaves 10000 in U

2. Arguments: none

3. Space required: 1000 cells

4. Temporary storage requirements: 1500 + 18X (number of input equations)

5. Alarms: none

6. Error returns: none

7. Error stops: 5450 in U if output criteria not satisfied (may be restarted if desired as errors will be indicated on printout)

103 in U if inconsistencies in designation are encountered

8. Input and output tape countings:

a. Input:

(1) Source tape: 30 5 102

b. Output:

(1) Output tape A: 05 4 103

9. Input and output formats:

- a. Input: 80 character card image of input equations.
Input equations written in standard FORTRAN format (see references).

(1) Input for card assignment only (jump key 1 not set):

- (a) Each term must consist of four alphanumeric characters.
- (b) The function must be the first term of the equation.
- (c) The only restrictions on spacing or locations on the card is that columns 72 through 80 be set aside for insertion of location when assigned.
- (d) The following characters are defined as operators when used in a logical equation:

space + - * / () _ , > .

- (e) All entries following . / * , () are treated as remarks.
- (f) A maximum of 16 input terms may be used in an equation
- (g) A maximum of 100 output uses will be compiled for a function
- (h) When inserted anywhere following the equation, these symbols define unique types of cards:

- . or space only inverters (series 10 and 20)
- * flip-flops (series 30) (one flip-flop per card)
- " input cards (01) (three inverters per card)
- / output cards (02) (three inverters per card)
- , clock cards (01) (two oscillators per card)

- (single inverter (335) (three inverters per card)
-) diode fanout (304) (three sets of three diodes each per card)

(i) If flip-flops (series 30) designated, the pair input equations should be adjacent, and the implicit input should be the first OR term.

(2) Input for complete program (jump key one set): In addition to (a) through (i) above, the location must be typed into columns 77 through 80 and should have the following format:

Input card column	77	78 and 79	80
Meaning	ROW	COLUMN	SECTION
Allowable contents	A thru R	01 thru 99	A for 10 series A or C or 20 and 30 series or clock 304 A, B or C for 60 series or 336

Columns 73 through 76 can be used to identify chassis.

b. Outputs: 120 character line image in program control format for listing on output tape A.

(1) Outputs for card assignment only (jump key 1 not set):

- (a) comments lines where applicable
- (b) input equation lines as read in
- (c) output lines with card type followed by list of output locations (following each input line)
- (d) tabulation of the number of cards necessary to

implement the design.

- (e) If any errors occur, such as too many inputs or outputs, no assignment is made and an error symbol is placed in the output line (along with an error stop).

(2) Outputs for complete program (jump key one set):

- (a) as above
- (b) input equation lines minus the location information
- (c) output lines with location and card type followed by list of output locations (following each input line)
- (d) as above
- (e) tabulation of wiring data containing the following:
 - (e-1) origin and destination by row, column and pin number, if an internal card or by designation if external input
 - (e-2) designations of the above origin and destinations
 - (e-3) wire length in inches
 - (e-4) separation of added groups by symbol * in left column

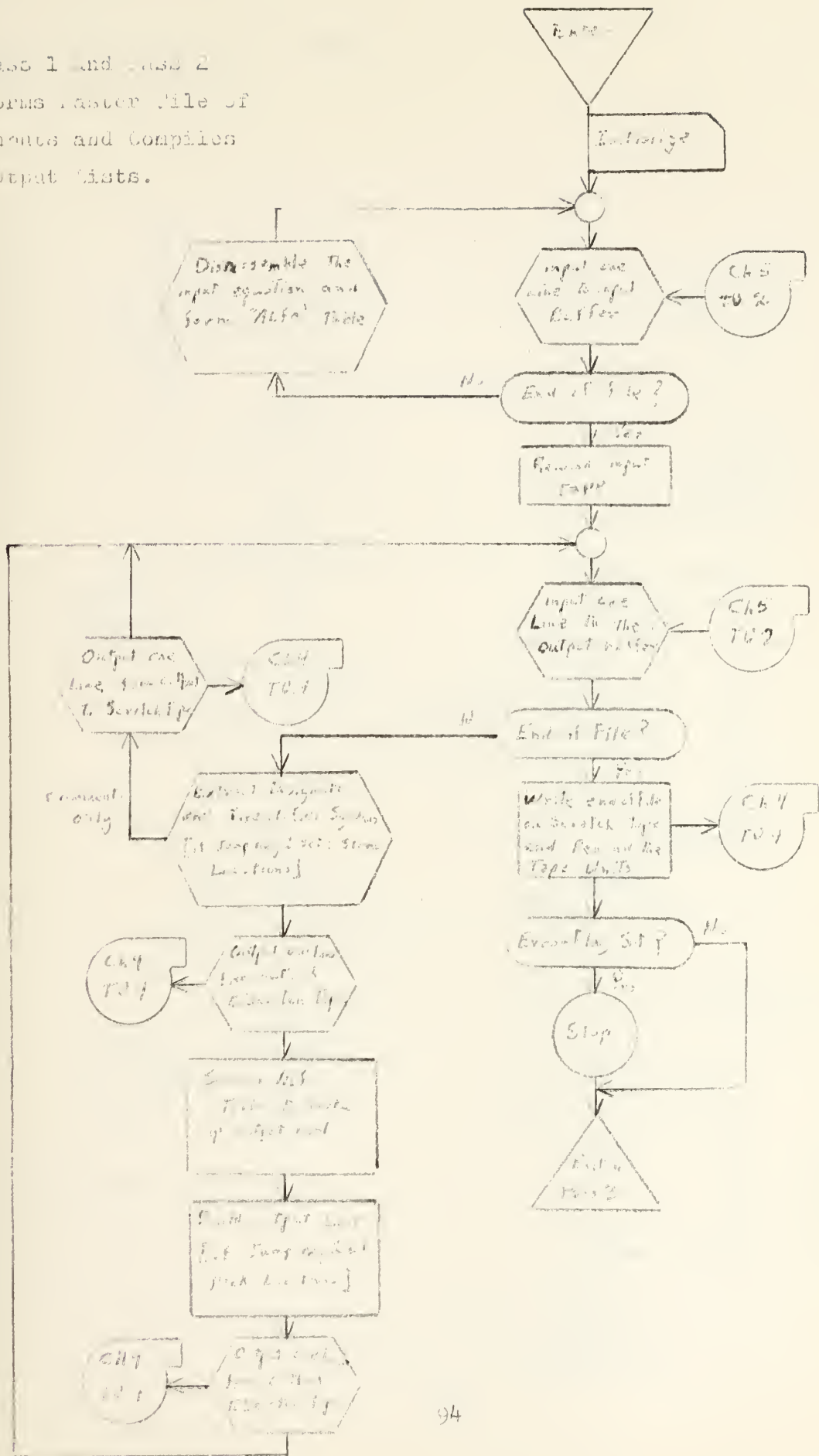
10. Selective jump and stop settings:

- a. First run: none - to obtain card types
- b. Second run: jump key one set - to allow processing of

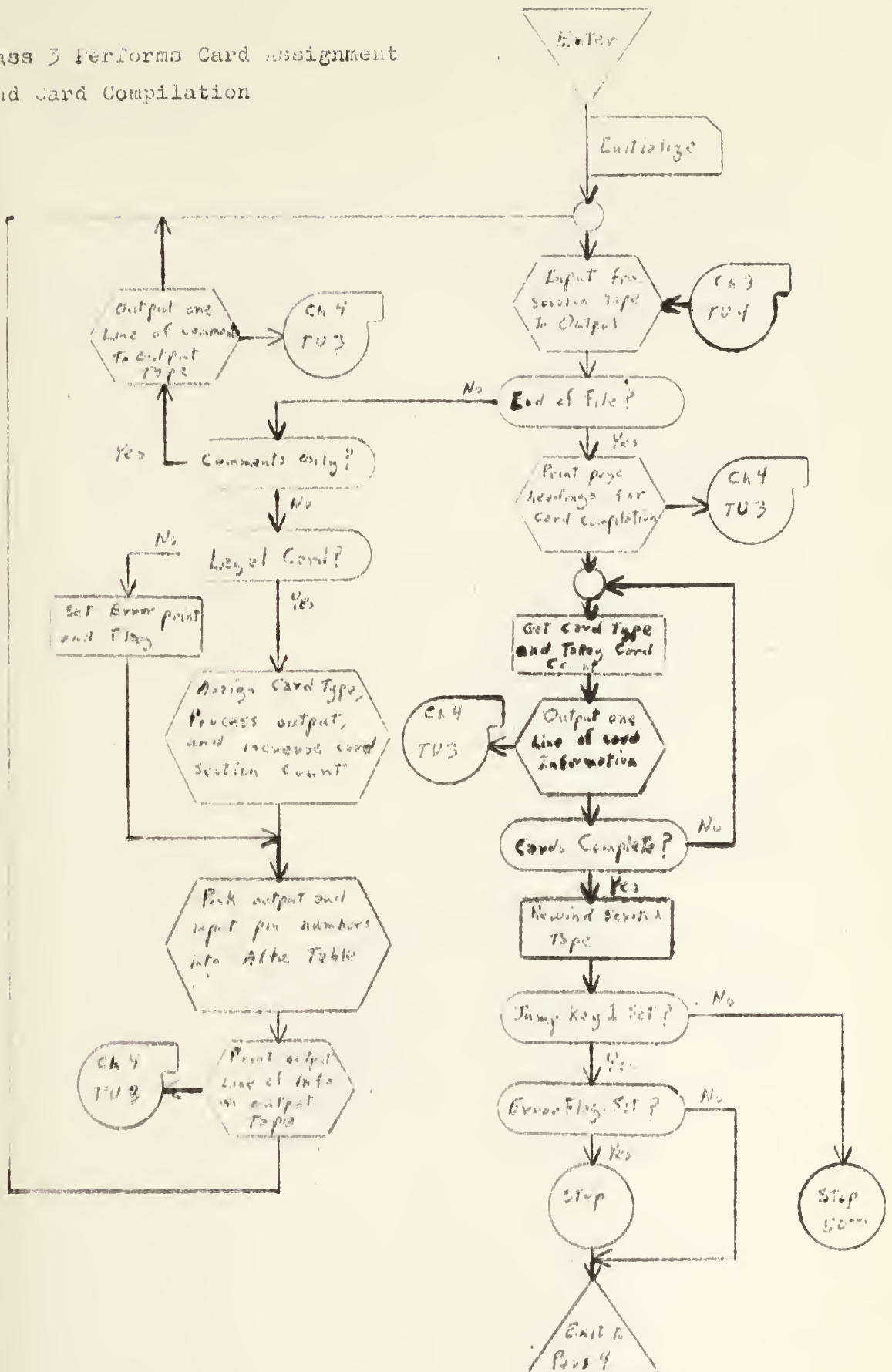
location information

11. Timing: depends on number of input equations
12. Accuracy: not applicable
13. Cautions to user: No tape errors are checked in the routine.
14. Equipment configuration: 1604 with two 1607 units;
1607 tape mountings to include a "scratch tape" on Ch4 104
15. References:
 - a. 1604 Computer Instruction Book, Vol. 1, Description and Operations, Control Data Corporation
 - b. 1604 Computer Instruction Book, Vol. 2, Principles of Operations, Control Data Corporation
 - c. H. Loberman and A. Weinberger, Formal Procedures for Connecting Terminals with a Minimum Total Wire Length, J. Assoc. Computing Machinery, Vol. 4, no. 4, pp. 428-437, October, 1957

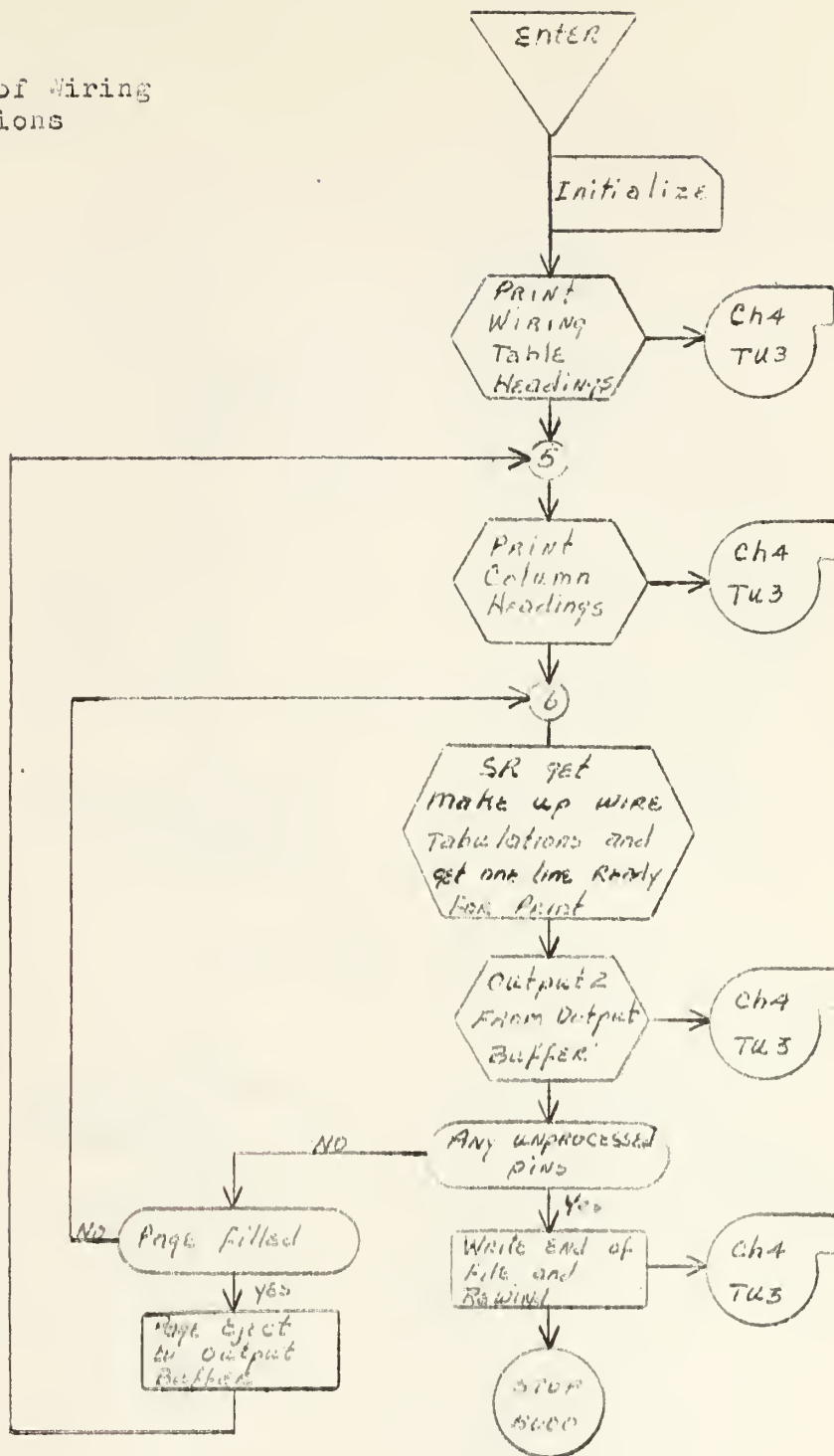
Pass 1 and Pass 2
Forms Master File of
Inputs and Compiles
Output Lists.



Pass 3 Performs Card Assignment
and Card Compilation



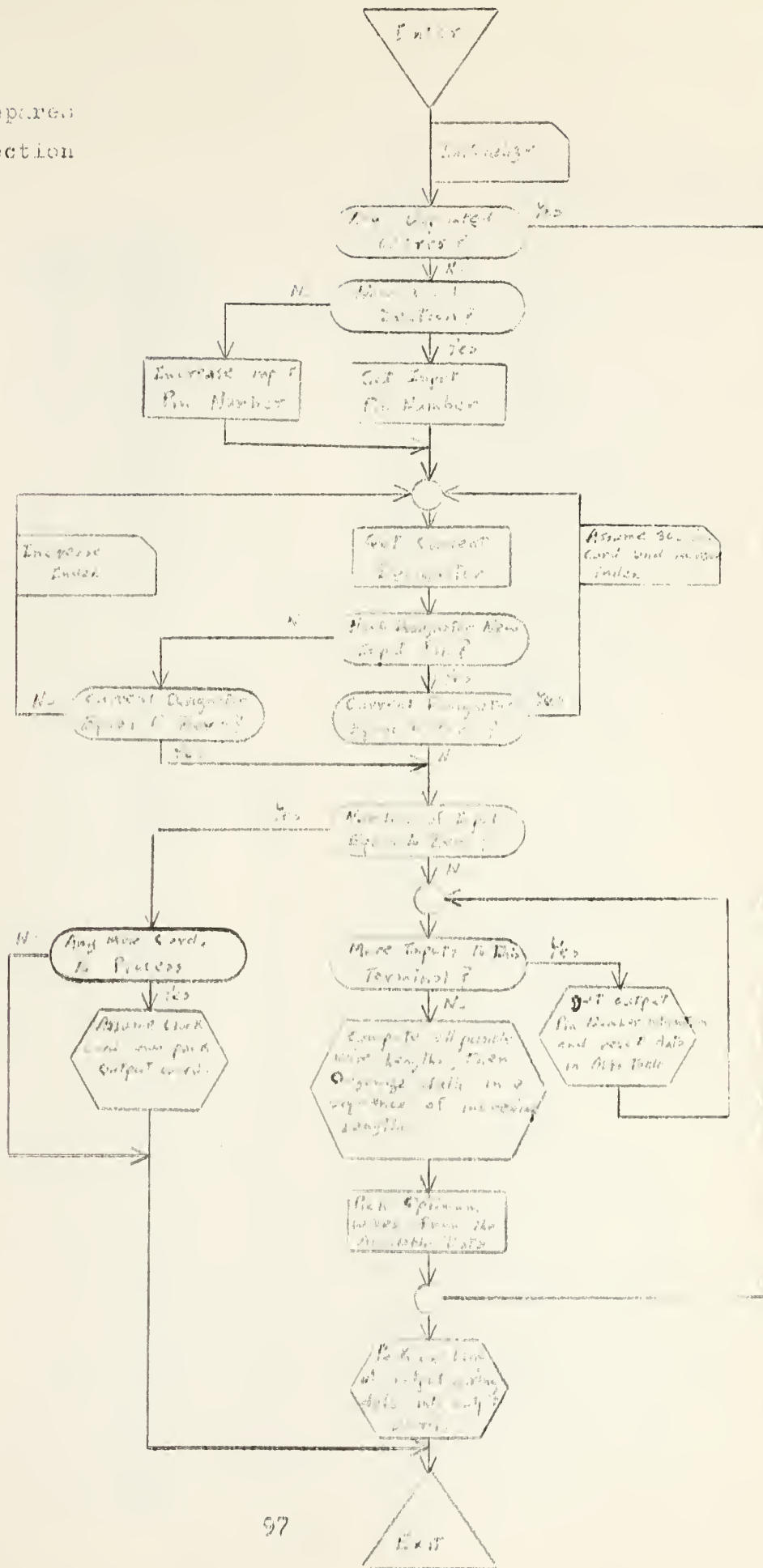
Pass 4
 Makeup of Wiring
 Tabulations



Subroutine WAT

Chooses and prepares

best wire connection




```

05000 50 1 000000
      10 0 000000
05001 50 1 000000
      50 0 000000
05002 54 1 677000
      75 0 050001
05003 20 0 05253
      20 0 05310
05004 20 0 06067
      20 0 06064
05005 50 0 000000
      74 7 520000
05006 10 0 05267
      61 0 000005
05007 74 0 52022
      74 7 520000
05010 74 5 05255
      74 7 520000
05011 74 7 52006
      75 0 05044
05012 74 5 05267
      50 0 000000
05013 74 0 52005
      57 1 07226
05014 12 0 07226
      20 0 05242
05015 75 4 05202
      50 0 000000
05016 50 0 000000
      74 7 520000
05017 10 0 05302
      61 0 000005
05020 74 0 52022
      74 7 520000
05021 74 5 05270
      74 7 520000
05022 74 7 52006
      75 0 05037
05023 74 5 05302
      74 7 420000
05024 74 0 42042
      74 0 42003
05025 74 7 42000
      74 0 42005
05026 74 0 52005
      12 0 05253
05027 22 0 05456
      10 0 000000
05030 20 0 05253
      76 0 05456
05031 75 0 000000
      74 7 420000
05032 20 0 05246
      72 0 05310
05033 10 0 05306
      61 0 000004
05034 74 0 42042
      74 7 420000
05035 74 4 05267
      74 7 420000
05036 12 0 05246
      75 0 05031
05037 75 4 05077
      50 0 000000
05040 75 4 05031
      50 0 000000

```

INPUT

ELEV

OUTPUT

TWELVE

```

ORG 5000
REM PART ONE OF THE LOGI
REM SUBROUTINE WHICH COL
REM LOGICAL EQUATIONS AN
REM ON THE LINE IMMEDIAT
ENI 1 0
ENA 0 0
STA 1 0
ENI 1 0
ISK 1 67700
SLJ 0 7-1
STA 0 FLAG
STA 0 PAGE
STA 0 WAIT
STA 0 COUNT
LNI 0 0
EXF 7 52000
ENA 0 INBUF+100
SAL 0 5
EXF 0 52022
EXF 7 52000
EXF 5 INBUF
EXF 7 52000
EXF 7 52006
SLJ 0 DISASS
EXF 5 INBUF+100
ENI 0 0
EXF 0 52005
SIL 1 GCFER
LDA 0 GCFER
STA 0 TEMP+1
SLJ 4 FILL
ENI 0 0
ENI 0 0
EXF 7 52000
ENA 0 OUTBUF+110
SAL 0 5
EXF 0 52022
EXF 7 52000
EXF 5 OUTBUF+1
EXF 7 52000
EXF 7 52006
SLJ 0 TWELVE
EXF 5 OUTBUF+110
EXF 7 42000
EXF 0 42042
EXF 0 42003
EXF 7 42000
EXF 0 42005
EXF 0 52005
LDA 0 FLAG
AIP 0 PASS3
ENA 0 0
STA 0 FLAG
SLS 0 PASS3
SLJ 0 0
EXF 7 42000
STA 0 TEMP+5
RAO 0 PAGE
ENA 0 OUTBUF+150
SAL 0 4
EXF 0 42042
EXF 7 42000
EXF 4 OUTBUF
EXF 7 42000
LDA 0 TEMP+5
SLJ 0 OUTPUT
SLJ 4 EXTRACT
ENI 0 0
SLJ 4 OUTPUT
ENI 0 0

```


05041	12 0 05252		LDA	0	SPACE
	20 0 05267		STA	0	OUTBUF
05042	20 0 05305		STA	0	OUTBUF+140
	12 0 05241		LDA	0	TEMP
05043	50 0 00000		ENI	0	0
	75 0 05125		SLJ	0	SEARCH
05044	50 2 00000	DISASS	ENI	2	0
	50 3 00000		ENI	3	0
05045	50 4 00000		ENI	4	0
	50 5 00000		ENI	5	0
05046	50 6 00000		ENI	6	0
	10 0 00000		ENA	0	0
05047	16 2 05255	ONE	LDO	2	INBUF
	50 0 00000		ENI	0	0
05050	05 0 00006	TWO	ALS	0	6
	20 0 05241		STA	0	TEMP
05051	10 0 00000		ENA	0	0
	07 0 00006		LLS	0	6
05052	50 6 00013		ENI	6	110
	50 0 00000		ENI	0	0
05053	64 6 05206		EQS	6	LIST
	75 0 05063		SLJ	0	THREE
05054	10 6 00000		ENA	6	0
	22 1 05056		AJP	1	/+2
05055	10 5 00000		ENA	5	0
	22 0 05072		AJP	0	FIVE+2
05056	10 6 00000		ENA	6	0
	15 0 05254		SUB	0	UNITS
05057	22 3 05071		AJP	3	FIVE+1
	51 6 77770		INI	6	-7
05060	55 6 05061		IJP	6	/+1
	75 0 05075		SLJ	0	OR
05061	55 6 05062		IJP	6	/+1
	75 0 05075		SLJ	0	OR
05062	10 0 00000		ENA	0	0
	75 0 05067		SLJ	0	FOUR
05063	70 0 05241	THREE	RAD	0	TEMP
	50 0 00000		ENI	0	0
05064	54 3 00003		ISK	3	3
	75 0 05067		SLJ	0	FOUR
05065	70 1 16000		RAD	1	ALFA
	51 5 00001		INI	5	1
05066	51 1 00001		INI	1	1
	10 0 00000		ENA	0	0
05067	54 4 00007	FOUR	ISK	4	7
	75 0 05050		SLJ	0	TWO
05070	54 2 00010	FIVE	ISK	2	10
	75 0 05047		SLJ	0	ONE
05071	54 5 00022		ISK	5	22
	75 0 05073		SLJ	0	/+2
05072	75 0 05005		SLJ	0	INPUT
	50 0 00000		ENI	0	0
05073	10 0 00000		ENA	0	0
	20 1 16000		STA	1	ALFA
05074	51 1 00001		INI	1	1
	75 0 05071		SLJ	0	/-3
05075	12 0 05455	OR	LDA	0	BIT48
	20 1 16000		STA	1	ALFA
05076	10 0 00000		ENA	0	0
	75 0 05067		SLJ	0	FOUR
05077	75 0 00000	EXTRACT	SLJ	0	0
	10 0 00000		ENA	0	0
05100	50 5 00000		ENI	5	0
	16 0 05270		LDO	0	OUTBUF+1
05101	05 0 00006		ALS	0	6
	20 0 05241		STA	0	TEMP
05102	10 0 00000		ENA	0	0
	50 0 00000		ENI	0	0
05103	07 0 00006		LLS	0	6
	50 6 00013		ENI	6	110
05104	64 6 05206		EQS	6	LIST
	75 0 05107		SLJ	0	/+3
05105	10 6 00000		ENA	6	0

05106	22	0	05172
	75	0	05102
	50	0	00C00
05107	70	0	05241
	50	0	00C00
05110	54	5	00C03
	75	0	05101
05111	50	3	00C00
	50	2	00C00
05112	75	5	05173
	50	0	00C00
05113	16	2	05270
	50	0	00C00
05114	10	0	00C00
	50	0	00C00
05115	07	0	00C06
	50	6	00C07
05116	64	6	05206
	75	0	05120
05117	75	0	05122
	50	0	00C00
05120	54	3	00C07
	75	0	05114
05121	54	2	00C10
	75	0	05113
05122	12	6	05232
	20	0	05205
05123	12	6	05221
	61	0	05247
05124	75	0	05C77
	50	0	00C00
05125	53	1	05242
	50	3	00C00
05126	16	0	06113
	50	0	00C00
05127	66	1	16C00
	75	0	05141
05130	57	1	07226
	12	0	07226
05131	04	0	00C00
	22	0	05141
05132	25	0	05230
	23	0	05140
05133	57	1	07226
	12	0	07226
05134	21	0	05231
	15	0	05231
05135	20	0	05231
	53	2	05231
05136	16	0	06113
	44	2	16C00
05137	20	3	05311
	51	3	00C01
05140	12	0	05241
	75	0	05126
05141	75	4	05202
	50	0	00C00
05142	75	1	05143
	75	0	05144
05143	12	0	06C66
	20	0	05270
05144	55	3	05145
	75	0	05167
05145	10	3	00C00
	15	0	05247
05146	22	3	05150
	12	0	05251
05147	20	0	05267
	72	0	05253
05150	75	0	05152
	50	0	00C00
05151	75	4	05202
	50	0	00C00

SEARCH

SIX

SEVEN

BUILD

AJP	0	TENA-1
SLJ	0	/-4
FNI	0	0
RAD	0	TEMP
ENI	0	0
ISK	5	3
SLJ	0	/-7
ENI	3	0
ENI	2	0
SLJ	4	MAKEX
ENI	0	0
LDO	2	OUTBUF+1
ENI	0	0
ENA	0	0
ENI	0	0
LLS	0	6
ENI	6	7
ECS	6	LIST
SLJ	0	/+2
SLJ	0	/+3
ENI	0	0
ISK	3	7
SLJ	0	/-4
ISK	2	8D
SLJ	0	/-6
LIA	6	CARD21
STA	0	OUTBUF+140
LIA	6	CHECK
SAL	0	EIGHT
SLJ	0	EXTRACT
ENI	0	0
LIL	1	TEMP+1
ENI	3	0
LIO	0	LCMASK
ENI	0	0
REQ	1	ALPHA
SLJ	0	BUILD
SIL	1	GOFER
LIA	0	GOFER
REQ	0	0
AJP	0	BUILD
DVI	0	INCRM
QJP	0	SEVEN
SIL	1	GOFER
LIA	0	GOFER
SIO	0	DECRM
SUB	0	DECRM
STA	0	DECRM
LIL	2	DECRM
LDO	0	LCMASK
LIL	2	ALPHA
STA	3	BETA
INI	3	1
LIA	0	TEMP
SLJ	0	SIX
SLJ	4	FILL
ENI	0	0
SLJ	1	/+1
SLJ	0	/+2
LIA	0	HOLD
STA	0	OUTBUF+1
IJP	3	/+1
SLJ	0	PRNONE
ENA	3	0
SUB	0	EIGHT
AJP	3	/+2
LIA	0	STAR
STA	0	OUTBUF
RAD	0	FLAG
SLJ	0	/+2
ENI	0	0
SLJ	4	FILL
ENI	0	0

05152	50	4	00C02
	10	3	00C00
05153	60	0	05162
	60	0	05171
05154	50	3	00C00
	50	0	00C00
05155	16	0	05250
	12	3	05311
05156	07	0	00030
	50	0	00000
05157	20	4	05270
	50	0	00C00
05160	54	4	00C05
	75	0	05171
05161	75	4	05C31
	50	0	00C00
05162	54	3	00C00
	75	0	05164
05163	75	0	05173
	50	0	00C00
05164	75	4	05202
	50	0	00C00
05165	12	0	05232
	20	0	05270
05166	50	4	00C02
	75	0	05155
05167	12	0	05306
	20	0	05272
05170	75	0	05172
	50	0	00C00
05171	54	3	00C00
	75	0	05155
05172	75	4	05C31
	50	0	00C00
05173	75	4	05202
	50	0	00C00
05174	75	4	05C31
	50	0	00C00
05175	20	0	05246
	10	0	00110
05176	65	0	05310
	75	0	05C16
05177	10	0	00C00
	20	0	05310
05200	12	0	05307
	20	0	05267
05201	12	0	05246
	75	0	05C16
05202	75	0	00C00
	50	5	00C00
05203	12	5	05252
	20	5	05267
05204	54	5	00C16
	75	0	05203
05205	75	0	05202
	50	0	00C00
05206	00	0	00C00
	00	0	00C73
05207	00	0	00C00
	00	0	00C54
05210	00	0	00C00
	00	0	00C53
05211	00	0	00C00
	00	0	00C21
05212	00	0	00C00
	00	0	00C33
05213	00	0	00C00
	00	0	00C34
05214	00	0	00C00
	00	0	00C74
05215	00	0	00C00
	00	0	00C60
05216	00	0	00C00

NINE

PR NONE

TEN

TENA

FILL

LIST

ENI	4	2
ENA	3	0
SAU	0	NINE+5
SAU	0	TEN
ENI	3	0
ENI	0	0
LDO	0	COMMA
LDA	3	BETA
LLS	0	240
ENI	0	0
STA	4	OUTBUF+1
ENI	0	0
ISK	4	130
SLJ	0	TEN
SLJ	4	OUTPUT
ENI	0	0
ISK	3	0
SLJ	0	7+2
SLJ	0	TENA
ENI	0	0
SLJ	4	FILL
ENI	0	0
LDA	0	CARD21
STA	0	OUTBUF+1
ENI	4	2
SLJ	0	NINE
LDA	0	NCNF
STA	0	OUTBUF+3
SLJ	0	TEN+1
ENI	0	0
ISK	3	0
SLJ	0	NINE
SLJ	4	OUTPUT
ENI	0	0
SLJ	4	FILL
ENI	0	0
SLJ	4	OUTPUT
ENI	0	0
STA	0	TEMP+5
ENA	0	720
THS	0	PAGE
SLJ	0	ELEV
ENA	0	0
STA	0	PAGE
LDA	0	EJECT
STA	0	OUTBUF
LDA	0	TEMP+5
SLJ	0	ELEV
SLJ	0	0
ENI	5	0
LDA	0	SPACE
STA	5	OUTBUF
ISK	5	140
SLJ	0	7-1
SLJ	0	FILL
ENI	0	0
OCT		73
OCT		54
OCT		53
OCT		21
OCT		33
OCT		34
OCT		74
OCT		60
OCT		13

05217	00 0 00013		OCT	14	
	00 0 00000				
05220	00 0 00014		OCT	20	
	00 0 00020				
05221	00 0 00000	CHECK	OCT	10	
	00 0 00010				
05222	00 0 00000		OCT	5	
	00 0 00005				
05223	00 0 00000		OCT	2	
	00 0 00002				
05224	00 0 00000		OCT	1	
	00 0 00001				
05225	00 0 00000		OCT	5	
	00 0 00005				
05226	00 0 00000		OCT	1	
	00 0 00001				
05227	00 0 00000		OCT	3	
	00 0 00003				
05230	00 0 00000	INCRM	OCT	22	
	00 0 00022				
05231	00 0 00000	DECRM	BSS	1	
	00 0 00000				
05232	20 2 02020	CARD21	BCD	/	.
	20 2 02073				
05233	20 2 02020	CARD31	BCD	/	*
	20 2 02054				
05234	20 2 02020	CARD61	BCD	/	3
	20 2 02053				
05235	20 2 02020	CARD62	BCD	/	/
	20 2 02021				
05236	20 2 02020	CARD01	BCD	/	,
	20 2 02033				
05237	20 2 02020	CARDS36	BCD	/	(
	20 2 02054				
05240	20 2 02020	CARDS04	BCD	/)
	20 2 02074				
05241	00 0 00000	TEMP	BSS	6	
	00 0 00000				
05247	00 0 00000	EIGHT	OCT	10	
	00 0 00010				
05250	33 2 02020	COMMA	BCD	/,	
	20 2 02020				
05251	20 2 02020	STAR	BCD	/	*
	20 2 42020				
05252	20 2 02020	SPACE	BCD	/	
	20 2 02020				
05253	00 0 00000	FLAG	BSS	1	
	00 0 00000				
05254	00 0 00000	UNITS	OCT	7	
	00 0 00007				
05255	00 0 00000	INBUF	BSS	100	
	00 0 00000				
05267	00 0 00000	OUTBUF	BSS	150	
	00 0 00000				
05306	45 4 64565	NONE	BCD	/NONE	
	20 2 02020				
05307	01 2 02020	EJECT	BCD	/1	
	20 2 02020				
05310	00 0 00000	PAGE	BSS	1	
	00 0 00000				
05311	00 0 00000	BETA	BSS	1000	
	00 0 00000				
05455	60 0 00000	BI F48	OCT	600000000000000000	
	00 0 00000				
05456	50 1 00032	PASS3	REM	CARD ASSIGNMENT ROUTINE	
	10 0 00000		END	1 260	
05457	20 1 06027		LNA	0 0	
	55 1 05457		STA	1 ICCUNT	
05460	75 4 05700	PASS3A	LJP	1 /	
	50 0 00000		SLJ	4 INPUT2	
05461	74 7 32006		END	0 0	
			EXP	7 32006	

05462	75	0	05552
	74	3	05306
	75	4	05202
05463	12	0	06010
	20	0	05267
05464	75	4	05705
	50	0	00C00
05465	75	4	05717
	50	0	00C00
05466	10	0	06140
	60	0	05713
05467	12	0	06012
	60	0	05714
05470	75	4	05712
	50	0	00C00
05471	75	4	05717
	50	0	00C00
05472	10	0	06150
	60	0	05713
05473	12	0	06013
	60	0	05714
05474	75	4	05712
	50	0	00C00
05475	75	4	05717
	50	0	00C00
05476	10	0	06155
	60	0	05713
05477	12	0	06014
	60	0	05714
05500	75	4	05712
	50	0	00C00
05501	50	5	00C00
	75	4	05717
05502	12	0	05252
	20	0	05274
05503	20	0	05275
	50	0	00C00
05504	12	5	06116
	20	0	05271
05505	12	5	06027
	75	4	05512
05506	54	5	00021
	75	0	05502
05507	74	0	32C05
	12	0	05253
05510	75	1	05511
	76	0	05C00
05511	22	0	06163
	76	0	06163
05512	75	0	00C00
	50	6	00C00
05513	65	0	06C20
	51	6	00C01
05514	65	0	06C17
	51	6	00C01
05515	65	0	06016
	51	6	00C01
05516	65	0	06C15
	51	6	00C01
05517	55	6	05520
	75	0	05532
05520	16	6	06021
	21	0	05243
05521	04	0	00C00
	21	0	05241
05522	04	0	00C00
	25	6	06C15
05523	22	1	05524
	12	0	06107
05524	20	0	05244
	12	0	05241
05525	05	0	00C06
	14	0	05244

OCTBCD

SLJ	0	TEST
EXF	3	OUTBUF+150
SLJ	4	FILL
LDA	0	PAGEJ
STA	0	OUTBUF
SLJ	4	OUTPUT2
ENI	0	0
SLJ	4	CLRBUF
ENI	0	0
ENA	0	HEAD1
SAU	0	MSG+1
LDA	0	LNTH1
SAU	0	MSG+2
SLJ	4	MSG
ENI	0	0
SLJ	4	CLRBUF
ENI	0	0
ENA	0	HEAD2
SAU	0	MSG+1
LDA	0	LNTH2
SAU	0	MSG+2
SLJ	4	MSG
ENI	0	0
SLJ	4	CLRBUF
ENI	0	0
ENA	0	HEAD3
SAU	0	MSG+1
LDA	0	LNTH3
SAU	0	MSG+2
SLJ	4	MSG
ENI	0	0
ENI	5	0
SLJ	4	CLRBUF
LDA	0	SPACE
STA	0	OUTBUF+5
STA	0	OUTBUF+6
ENI	0	0
LDA	5	CARD
STA	0	OUTBUF+2
LDA	5	ICOUNT
SLJ	4	OCTBCD
ISK	5	170
SLJ	0	7-4
EXF	0	32005
LDA	0	FLAG
SLJ	1	7+1
SLS	0	5000
AJP	0	PASS4
SLS	0	PASS4
SLJ	0	0
ENI	6	0
IHS	0	REFR03
INI	6	1
IHS	0	REFR02
INI	6	1
IHS	0	REFR01
INI	6	1
IHS	0	REFR00
INI	6	1
IJP	6	7+1
SLJ	0	FRACT
LDO	6	MASK
STQ	0	TEMP+2
LNQ	0	0
STQ	0	TEMP
ENO	0	0
DVI	6	REFR00
AJP	1	7+1
LDA	0	ZERO
STA	0	TEMP+3
LDA	0	TEMP
ALS	0	6
ADD	0	TEMP+3

05526	20	0	05241		STA	0	TEMP
	21	0	05244		STQ	0	TEMP+3
05527	12	0	05244		LDA	0	TEMP+3
	55	6	05522		IJP	6	/-5
05530	12	0	05241		LDA	0	TEMP
	14	0	05243		ADD	0	TEMP+2
05531	20	0	05274		STA	0	OUTBUF+5
	50	0	00000		ENI	0	0
05532	10	5	00000	FRACT	ENA	5	0
	15	0	06026		SUB	0	TRIP
05533	22	2	05542		AJP	2	THIRD
	10	5	00000		ENA	5	0
05534	15	0	06025		SUB	0	DCUB
	22	2	05547		AJP	2	HALF
05535	12	0	05274	ITEST	LDA	0	OUTBUF+5
	15	0	05252		SUB	0	SPACE
05536	22	1	05540		AJP	1	OUTLINE
	12	0	05306		LDA	0	NCNE
05537	20	0	05274		STA	0	OUTBUF+5
	50	0	00000		ENI	0	0
05540	75	4	05705	OUTLINE	SLJ	4	OUTPUT2
	50	0	00000		ENI	0	0
05541	75	0	05512		SLJ	0	OCTBCD
	50	0	00000		ENI	0	0
05542	12	5	06040	THIRD	LDA	5	FCOUNT-9D
	22	0	05535		AJP	0	ITEST
05543	64	0	06015		EQS	0	RFR00
	75	0	05545		SLJ	0	/+2
05544	12	0	06072		LDA	0	ATHIRD
	75	0	05546		SLJ	0	/+2
05545	12	0	06073		LDA	0	BTHIRD
	50	0	00000		ENI	0	0
05546	20	0	05275		STA	0	OUTBUF+6
	75	0	05540		SLJ	0	OUTLINE
05547	12	5	06040	HALF	LDA	5	FCOUNT-9D
	22	0	05535		AJP	0	ITEST
05550	12	0	06074		LDA	0	AHALF
	20	0	05275		STA	0	OUTBUF+6
05551	75	0	05540		SLJ	0	OUTLINE
	50	0	00000		ENI	0	0
05552	12	0	05305	TEST	LDA	0	OUTBUF+14D
	50	1	00000		ENI	1	0
05553	64	0	05252		EQS	0	SPACE
	75	0	05560		SLJ	0	TEST2
05554	75	0	05556		SLJ	0	/+2
	50	0	00000		ENI	0	0
05555	75	5	05734	TEST1	SLJ	5	OUTPIN
	50	0	00000		ENI	0	0
05556	75	4	05705		SLJ	4	OUTPUT2
	50	0	00000		ENI	0	0
05557	75	0	05460		SLJ	0	PASS3A
	50	0	00000		ENI	0	0
05560	64	0	05234	TEST2	EQS	0	CARD61
	75	0	05570		SLJ	0	NEXT1
05561	75	4	05705	IOCD	SLJ	4	OUTPUT2
	50	0	00000		ENI	0	0
05562	75	4	05700		SLJ	4	INPUT2
	50	0	00000		ENI	0	0
05563	12	1	06134		LDA	1	CARD+14D
	20	0	05271		STA	0	OUTBUF+2
05564	72	1	06056		RAO	1	FCOUNT+5
	15	0	06077		SUB	0	TRIO
05565	22	0	05566		AJP	0	/+1
	75	0	05555		SLJ	0	TEST1
05566	10	0	00000		ENA	0	0
	20	1	06056		STA	1	FCOUNT+5
05567	72	1	06045		RAO	1	ICOUNT+14D
	75	0	05555		SLJ	0	TEST1
05570	64	0	05235	NEXT1	EQS	0	CARD62
	75	0	05655		SLJ	0	NEXT2
05571	50	1	00001		ENI	1	1
	75	0	05561		SLJ	0	IOCD
05572	64	0	05233	TEST3	EQS	0	CARD51

05573	75 0	05616		SLJ	0	TEST4
	50 6	00C12		ENI	6	100
	75 4	05723		SLJ	4	ORCOUNT
05574	75 4	05705		SLJ	4	OUTPUT2
	50 0	00C00		ENI	0	0
05575	75 4	05700		SLJ	4	INPUT2
	50 0	00C00		ENI	0	0
05576	12 0	06C63		LDA	0	ORCNT
	50 0	00C00		ENI	0	0
05577	64 0	06100		ECS	0	QUO
	75 0	05612		SLJ	0	TRY2
05600	12 1	06124	FFCD	LDA	1	CARD+6
	20 0	05271		STA	0	OUTBUF+2
05601	10 0	00C01		ENA	0	1
	20 0	06C70		STA	0	FFFLG
05602	72 1	06C35		RAO	1	ICOUNT+6
	75 5	05734		SLJ	5	OUTPIN
05603	75 4	05705		SLJ	4	OUTPUT2
	50 0	00C00		ENI	0	0
05604	75 4	05700		SLJ	4	INPUT2
	50 0	00C00		ENI	0	0
05605	75 4	05705		SLJ	4	OUTPUT2
	50 0	00C00		ENI	0	0
05606	75 4	05700		SLJ	4	INPUT2
	50 0	00C00		ENI	0	0
05607	12 1	06124		LDA	1	CARD+6
	20 0	05271		STA	0	OUTBUF+2
05610	12 0	05455		LDA	0	BIT48
	20 2	16C01		STA	2	ALFA+1
05611	75 0	05555		SLJ	0	TEST1
	50 0	00C00		ENI	0	0
05612	64 0	06C77	TRY2	ECS	0	TRIO
	75 0	05614		SLJ	0	TRY3
05613	50 1	00C01		ENI	1	1
	75 0	05600		SLJ	0	FFCD
05614	64 0	06C76	TRY3	ECS	0	QUAD
	75 0	05665		SLJ	0	ERROR1
05615	50 1	00C02		ENI	1	2
	75 0	05600		SLJ	0	FFCD
05616	64 0	05232	TEST4	ECS	0	CARD21
	75 0	05661		SLJ	0	TEST5
05617	50 6	00C12		ENI	6	100
	75 4	05723		SLJ	4	ORCOUNT
05620	75 4	05705		SLJ	4	OUTPUT2
	50 0	00C00		ENI	0	0
05621	75 4	05700		SLJ	4	INPUT2
	50 0	00C00		ENI	0	0
05622	75 4	05672		SLJ	4	OUTCOUNT
	50 0	00C00		ENI	0	0
05623	12 0	06C63		LDA	0	ORCNT
	50 0	00C00		ENI	0	0
05624	64 0	06C75		ECS	0	QUINT
	75 0	05632		SLJ	0	TRY6
05625	12 1	06101	UNCD	LDA	1	OUTEND
	50 0	00C00		ENI	0	0
05626	65 0	06C62		THS	0	OUTCNT
	75 0	05630		SLJ	0	7+2
05627	75 0	05670		SLJ	0	ERROR2
	50 0	00C00		ENI	0	0
05630	12 1	06122		LDA	1	CARD+4
	20 0	05271		STA	0	OUTBUF+2
05631	72 1	06C33		RAO	1	ICOUNT+4
	75 0	05555		SLJ	0	TEST1
05632	64 0	06102	TRY6	ECS	0	SEXT
	75 0	05634		SLJ	0	INVI
05633	50 1	00C01		ENI	1	1
	75 0	05625		SLJ	0	UNCD
05634	64 0	06C15	INVI	ECS	0	RFR00
	75 0	05647		SLJ	0	INV2
05635	12 1	06C75	INCC	LDA	1	QUINT
	50 0	00C00		ENI	0	0
05636	65 0	06C62		THS	0	OUTCNT
	75 0	05641		SLJ	0	SER20

05637	12	1	06116		LDA	1	CARD
	20	0	05271		STA	0	OUTBUF+2
05640	72	1	06027		RAC	1	ICOUNT
	75	0	05555		SLJ	0	TEST1
05641	51	1	00011	SER20	INI	1	90
	12	1	06116		LDA	1	CARD
05642	20	0	05271		STA	0	OUTBUF+2
	72	1	06040		RAC	1	ICOUNT+90
05643	15	0	06100		SUB	0	DUC
	22	0	05645		AJP	0	7+2
05644	75	0	05555		SLJ	0	TEST1
	50	0	00000		ENI	0	0
05645	10	0	00000		ENA	0	0
	20	1	06040		STA	1	ICOUNT+90
05646	72	1	06027		RAC	1	ICOUNT
	75	0	05555		SLJ	0	TEST1
05647	64	0	06100	INV2	EQS	0	DUC
	75	0	05651		SLJ	0	INV3
05650	50	1	00001		INI	1	1
	75	0	05635		SLJ	0	INCD
05651	64	0	06077	INV3	EQS	0	TRIO
	75	0	05653		SLJ	0	INV4
05652	50	1	00002		ENI	1	2
	75	0	05635		SLJ	0	INCD
05653	64	0	06076	INV4	EQS	0	QUAD
	75	0	05671		SLJ	0	ERROR3
05654	50	1	00003		ENI	1	3
	75	0	05635		SLJ	0	INCD
05655	64	0	05237	NEXT2	EQS	0	CARDS36
	75	0	05657		SLJ	0	NEXT3
05656	50	1	00002		INI	1	2
	75	0	05561		SLJ	0	ICCD
05657	64	0	05240	NEXT3	EQS	0	CARDS04
	75	0	05572		SLJ	0	TEST3
05660	50	1	00003		ENI	1	3
	75	0	05561		SLJ	0	ICCD
05661	64	0	05236	TEST5	EQS	0	CARD01
	75	0	05665		SLJ	0	ERROR1
05662	50	1	00004		INI	1	4
	75	4	05705		SLJ	4	OUTPUT2
05663	75	4	05700		SLJ	4	INPUT2
	50	0	00000		ENI	0	0
05664	75	0	05641		SLJ	0	SER20
	50	0	00000		ENI	0	0
05665	12	0	06103	ERROR1	LDA	0	TAGE
	50	0	00000		ENI	0	0
05666	20	0	05271		STA	0	OUTBUF+2
	72	0	05253		RAC	0	FLAG
05667	75	0	05555		SLJ	0	TEST1
	50	0	00000		ENI	0	0
05670	12	0	06104	ERROR2	LDA	0	OUTE
	75	0	05666		SLJ	0	7-2
05671	12	0	06105	ERROR3	LDA	0	INE
	75	0	05666		SLJ	0	7-3
05672	75	0	00000	OUTCOUNT	SLJ	0	0
	50	6	00013		ENI	6	110
05673	10	0	00000		ENA	0	0
	20	0	06062		STA	0	OUTCNT
05674	12	0	06110		LDA	0	CMASK
	16	0	06110		LDC	0	CMASK
05675	46	6	05272		SBL	6	OUTBUF+3
	22	1	05677		AJP	1	7+2
05676	72	0	06062		RAC	0	OUTCNT
	50	0	00000		ENI	0	0
05677	55	6	05674		IJP	6	7-3
	75	0	05672		SLJ	0	OUTCOUNT
05700	75	0	00000	INPUT2	SLJ	0	0
	74	7	32000		EXF	7	32000
05701	10	0	05306		ENA	0	OUTBUF+150
	61	0	00003		SAL	0	3
05702	74	0	32042		EXF	0	32042
	74	7	32000		EXF	7	32000
05703	74	3	05267		EXF	3	OUTBUF

05704	74 7 32000		EXF 7 32000
	75 0 05700		SLJ 0 INPUT2
	50 0 00000		ENI 0 0
05705	75 0 00000	OUTPUT2	SLJ 0 0
	74 7 42000		EXF 7 42000
05706	10 0 05306		ENA 0 OUTBUF+150
	61 0 00004		SAL 0 4
05707	74 0 42032		EXF 0 42032
	74 7 42000		EXF 7 42000
05710	74 4 05387		EXF 4 OUTBUF
	74 7 42000		EXF 7 42000
05711	75 0 05705		SLJ 0 OUTPUT2
	50 0 00000		ENI 0 0
05712	75 0 00000	MSG	SLJ 0 0
	50 5 00000		ENI 5 0
05713	12 5 00000		LDA 5 0
	20 5 05270		STA 5 OUTBUF+1
05714	54 5 00000		ISK 5 0
	75 0 05713		SLJ 0 /-1
05715	75 4 05705		SLJ 4 OUTPUT2
	50 0 00000		ENI 0 0
05716	75 0 05712		SLJ 0 MSG
	50 0 00000		ENI 0 0
05717	75 0 00000	CLRBUF	SLJ 0 0
	12 0 06011		LDA 0 DRSP
05720	20 0 05267		STA 0 OUTBUF
	50 5 00015		ENI 5 130
05721	12 0 05252		LDA 0 SPACE
	20 5 05270		STA 5 OUTBUF+1
05722	55 5 05721		IJP 5 /-1
	75 0 05717		SLJ 0 CLRBUF
05723	75 0 00000	ORCOUNT	SLJ 0 0
	10 0 00000		ENA 0 0
05724	20 0 06063		STA 0 ORCNT
	04 0 00000		ENO 0 0
05725	16 6 05267		LDO 6 OUTBUF
	50 4 00007		ENI 4 7
05726	07 0 00006		LLS 0 6
	50 0 00000		ENI 0 0
05727	64 0 06106		LDS 0 PLUS
	75 0 05731		SLJ 0 /+2
05730	72 0 06063		RAO 0 ORCNT
	50 0 00000		ENI 0 0
05731	10 0 00000		ENA 0 0
	55 4 05726		IJP 4 /-3
05732	55 6 05725		IJP 6 /-5
	72 0 06063		RAO 0 ORCNT
05733	75 0 05723		SLJ 0 ORCCUNT
	50 0 00000		ENI 0 0
05734	75 0 00000	OUTPIN	SLJ 0 0
	53 2 06067		LIL 2 WAIT
05735	16 0 06071		LDO 0 SMASK
	44 0 05271		LDL 0 OUTBUF+2
05736	15 0 06071		SUB 0 SMASK
	22 0 05752		AJP 0 TYP3
05737	16 0 06111		LDO 0 TFASK
	44 0 05271		LDL 0 OUTBUF+2
05740	22 1 05752		AJP 1 TYP3
	02 0 00001		GRS 0 1
05741	44 0 05271		LDL 0 OUTBUF+2
	22 1 05763		AJP 1 TYP2
05742	10 0 00001		ENA 0 1
	75 4 05771		SLJ 4 INPIN
05743	10 0 00014		ENA 0 120
	50 0 00000		ENI 0 0
05744	05 0 00030	MID	ALS 0 240
	70 2 16000		RAO 2 ALFA
05745	12 0 06070		LDA 0 FFFLC
	22 0 05750		AJP 0 /+3
05746	12 0 05455		LDA 0 RITH8
	20 2 16001		STA 2 ALFA+1
05747	10 0 00000		ENA 0 0
	20 0 06070		STA 0 FFFLC

05750	51 2 00022		INI	2 22
	57 2 06067		SIL	2 WAIT
05751	75 0 05734		SLJ	0 OUTPIN
	50 0 00000		FNI	0 0
05752	04 0 00077	TYP3	ENO	0 77
	44 0 05270		LDL	0 OUTBUF+1
05753	64 0 06114		EQS	0 PTA
	75 0 05756		SLJ	0 /+3
05754	10 0 00001		ENA	0 1
	75 4 00771		SLJ	4 INPIN
05755	10 0 00004		ENA	0 4C
	75 0 05744		SLJ	0 MID
05756	64 0 06115		EQS	0 PTB
	75 0 05761		SLJ	0 /+3
05757	10 0 00005		ENA	0 5
	75 4 05771		SLJ	4 INPIN
05760	10 0 00010		ENA	0 8D
	75 0 05744		SLJ	0 MID
05761	10 0 00011		ENA	0 9C
	75 4 05771		SLJ	4 INPIN
05762	75 0 05743		SLJ	0 MID-1
	50 0 00000		FNI	0 0
05763	04 0 00077	TYP2	ENO	0 77
	44 0 05270		LDL	0 OUTBUF+1
05764	64 0 06114		EQS	0 PTA
	75 0 05767		SLJ	0 /+3
05765	10 0 00001		ENA	0 1
	75 4 05771		SLJ	4 INPIN
05766	10 0 00006		ENA	0 6
	75 0 05744		SLJ	0 MID
05767	10 0 00007		ENA	0 7
	75 4 05771		SLJ	4 INPIN
05770	75 0 05743		SLJ	0 MID-1
	50 0 00000		FNI	0 0
05771	75 0 00000	INPIN	SLJ	0 0
	05 0 00036		ALS	0 30C
05772	70 2 16000		RAD	2 ALFA
	75 0 05771		SLJ	0 INPIN
05773	75 0 00000	MAKEX	SLJ	0 0
	12 0 05301		LDA	0 OUTBUF+10D
05774	20 0 06066		STA	0 RCLF
	41 0 06112		SCL	0 HIFASK
05775	07 0 00060		LLS	0 4MB
	12 0 05241		LDA	0 TEMP
05776	75 4 06001		SLJ	4 ENTER
	50 0 00000		FNI	0 0
05777	12 0 05252		LDA	0 SPACE
	20 0 05301		STA	0 OUTBUF+10D
06000	75 0 05773		SLJ	0 MAKEX
	50 0 00000		FNI	0 0
06001	75 0 00000	ENTER	SLJ	0 0
	57 6 06065		SIL	6 STORE
06002	53 6 06064		LIL	6 COUNT
	20 6 10000		STA	6 ARGUE
06003	21 6 13000		STO	6 VALUE
	50 0 00000		FNI	0 0
06004	54 6 02777		ISK	6 2777
	75 0 06006		SLJ	0 /+2
06005	04 0 00000		ENO	0 0
	75 0 06007		SLJ	0 /+2
06006	50 0 00000		FNI	0 0
	57 6 06064		SIL	6 COUNT
06007	53 6 06065		LIL	6 STORE
	75 0 06001		SLJ	0 ENTER
06010	01 2 02020	PAGEJ	BCD	/1
	20 2 02020			
06011	12 2 02020	DRSP	RCD	/0
	20 2 02020			
06012	00 0 00000	LNGETH1	DEC	7
	00 0 00007			
06013	00 0 00000	LNGETH2	DEC	4
	00 0 00004			
06014	00 0 00000	LNGETH3	DEC	5

06015	00 0 00005	REF00	OCT	1
06016	00 0 00000	REF01	OCT	12
06017	00 0 00012	REF02	OCT	144
06020	00 0 00000	REF03	OCT	1750
06021	00 0 01750	MARK	OCT	2020202020202000
06022	20 2 02000		OCT	2020202020200000
06023	20 2 02000		OCT	2020202020000000
06024	20 2 02000		OCT	2020202000000000
06025	00 0 00000	DOUB	DEC	9
06026	00 0 00011	TRIP	DEC	14
06027	00 0 00016	ICOUNT	BSS	180
06051	00 0 00000	FCOUNT	BSS	90
06062	00 0 00000	QUICNT	BSS	1
06063	00 0 00000	ORCNT	BSS	1
06064	00 0 00000	COUNT	BSS	1
06065	00 0 00000	STORE	BSS	1
06066	00 0 00000	HOLD	BSS	1
06067	00 0 00000	WAIT	BSS	1
06070	00 0 00000	FFFLC	BSS	1
06071	00 0 02200	SMASK	OCT	200000000000
06072	20 2 00121	ATHIRD	OCT	2020012103202020
06073	03 2 02020	BTHIRD	OCT	2020022103202020
06074	20 2 00121	AHALF	OCT	2020012102202020
06075	00 0 00000	QUINT	OCT	5
06076	00 0 00005	QUAD	OCT	4
06077	00 0 00004	TRIO	OCT	3
06100	00 0 00003	DUB	OCT	2
06101	00 0 00002	OUTEND	OCT	7
06102	00 0 00007	SFXT	OCT	6
06103	00 0 00006	TAGE	OCT	54542020
06104	54 5 42020	QUIE	OCT	5454542020
06105	00 0 05454	INE	OCT	545454542020
06106	54 5 42020	PLUS	OCT	60
06107	00 0 00000	ZERO	OCT	12
06110	00 0 00000	CMASK	OCT	33000000
06111	33 0 00000	TMASK	OCT	400000000
	00 0 00004			
	00 0 00000			

06112	77 7 77777	HIMASK	OCT	7777777700000000
	00 0 00000			
06113	00 0 00000	LOMASK	OCT	77777777
	77 7 77777			
06114	00 0 00000	PTA	OCT	61
	00 0 00001			
06115	00 0 00000	PTI	OCT	62
	00 0 00002			
06116	20 2 02001	GARD	BCD	/ 11
	01 2 02000			
06117	20 2 02001		BCD	/ 12
	02 2 02020			
06120	20 2 02001		BCD	/ 13
	03 2 02020			
06121	20 2 02001		BCD	/ 14
	04 2 02020			
06122	20 2 02001		BCD	/ 15
	05 2 02020			
06123	20 2 02001		BCD	/ 16
	06 2 02020			
06124	20 2 02003		BCD	/ 31
	01 2 02020			
06125	20 2 02003		BCD	/ 32
	02 2 02020			
06126	20 2 02003		BCD	/ 33
	03 2 02020			
06127	20 2 02002		BCD	/ 21
	01 2 02020			
06130	20 2 02002		BCD	/ 22
	02 2 02020			
06131	20 2 02002		BCD	/ 23
	03 2 02020			
06132	20 2 02002		BCD	/ 24
	04 2 02020			
06133	20 2 02012		BCD	/ 01
	01 2 02020			
06134	20 2 02006		BCD	/ 61
	01 2 02020			
06135	20 2 02006		BCD	/ 62
	02 2 02020			
06136	20 2 02203		BCD	/ S36
	06 2 02020			
06137	20 2 02212		BCD	/ S04
	04 2 02020			
06140	24 2 02220	HEAD1	BCD	/U S NAVA
	45 6 12561			
06141	43 2 04746		BCD	/L POST G
	22 2 32067			
06142	51 6 16424		BCD	/RADUATE
	61 2 36520			
06143	22 6 37046		BCD	/SCHOOL
	46 4 32020			
06144	20 2 06461		BCD	/ DATA P
	23 6 12047			
06145	51 4 66365		BCD	/RCCFSSIN
	22 2 27145			
06146	67 2 04361		BCD	/G LABORA
	62 4 65161			
06147	23 4 65130		BCD	/ICRY
	20 2 02020			
06150	20 2 02020	HEAD2	BCD	/
	20 2 02020			
06151	63 4 64447		BCD	/CCMPILAT
	71 4 36123			
06152	71 4 64520		BCD	/ION OF C
	46 6 62063			
06153	61 5 16420		BCD	/ARD ASSI
	61 2 22271			
06154	67 4 54465		BCD	/GNMENTS
	45 2 32220			
06155	20 2 02020	HEAD3	BCD	/
	20 2 02020			
06156	63 6 15164		BCD	/CARD TYP

06157	20 2 33047		BCD	/F
	65 2 02020			
06160	20 2 02020		BCD	/
	20 2 02020			
06161	45 2 44462		BCD	/NUMBER 0
	65 5 12046			
06162	66 2 06361		BCD	/F CARDS
	51 6 42220			
06163	50 1 00000	HA534	ENI	1 0
	50 2 00000		ENI	2 0
06164	50 3 00000		ENI	3 0
	50 4 00000		ENI	4 0
06165	50 6 00002		ENI	6 2
	10 0 00000		ENA	0 0
06166	20 0 06027		STA	0 ICOUNT
	20 0 06067		STA	0 WAIT
06167	20 0 06066		STA	0 HOLD
	75 4 05202		SLJ	4 FILL
06170	12 0 06010		LDA	0 PAGEJ
	20 0 05267		STA	0 OUTBUF
06171	75 4 05705		SLJ	4 OUTPUT2
	50 0 00000		ENI	0 0
06172	75 4 05717		SLJ	4 CLRBUF
	50 0 00000		ENI	0 0
06173	10 0 06140		ENA	0 HEAD1
	60 0 05713		SAU	0 MSG+1
06174	12 0 06012		LDA	0 LENGTH1
	60 0 05714		SAU	0 MSG+2
06175	75 4 05712		SLJ	4 MSG
	50 0 00000		ENI	0 0
06176	75 4 05717		SLJ	4 CLRBUF
	50 0 00000		ENI	0 0
06177	10 0 06560		ENA	0 HEAD4
	60 0 05713		SAU	0 MSG+1
06200	12 0 06556		LDA	0 LENGTH4
	60 0 05714		SAU	0 MSG+2
06201	75 4 05712		SLJ	4 MSG
	50 0 00000		ENI	0 0
06202	75 0 06206		SLJ	0 ONLY
	50 0 00000		ENI	0 0
06203	75 4 05202	NXTD	SLJ	4 FILL
	50 0 00000		ENI	0 0
06204	12 0 06010		LDA	0 PAGEJ
	20 0 05267		STA	0 OUTBUF
06205	75 4 05705		SLJ	4 OUTPUT2
	50 0 00000		ENI	0 0
06206	75 4 05717	ONLY	SLJ	4 CLRBUF
	50 0 00000		ENI	0 0
06207	10 0 06565		ENA	0 HEAD5
	60 0 05713		SAU	0 MSG+1
06210	12 0 06557		LDA	0 LENGTH5
	60 0 05714		SAU	0 MSG+2
06211	75 4 05712		SLJ	4 MSG
	50 0 00000		ENI	0 0
06212	75 4 05717	WLINE	SLJ	4 CLRBUF
	50 0 00000		ENI	0 0
06213	75 4 06223		SLJ	4 GET
	50 0 00000		ENI	0 0
06214	75 4 05705		SLJ	4 OUTPUT2
	50 0 00000		ENI	0 0
06215	12 0 05277		LDA	0 OUTBUF+80
	41 0 05252		SCL	0 SPACE
06216	22 1 06221		AJP	1 /+3
	50 0 00000		ENI	0 0
06217	74 0 42003		EXF	0 42003
	74 7 42000		EXF	7 42000
06220	74 0 42005		EXF	0 42005
	76 0 05000		SLS	0 5000
06221	54 6 00043		ISK	6 350
	75 0 06212		SLJ	0 WLINE
06222	75 0 06203		SLJ	0 NXTD
	50 0 00000		ENI	0 0

06223	75 0	00C00	. GET	SLJ	0 0
	10 2	00C00		ENA	2 0
06224	22 1	06264		AJP	1 PREP
	12 0	06027		LDA	0 ICCOUNT
06225	22 1	06321		AJP	1 UDAT
	12 3	16C00		LDA	3 ALFA
06226	01 0	00036		ARS	0 300
	20 0	06611		STA	0 PINNI
06227	10 0	00C01		ENA	0 1
	20 0	06027		STA	0 ICCOUNT
06230	51 1	00001	GOT	INI	1 1
	16 0	06113		LDO	0 LCMASK
06231	44 1	16C00		LDL	1 ALFA
	20 2	06603		STA	2 AND
06232	36 1	16C01		SSK	1 ALFA+1
	75 0	06235		SLJ	0 PICK
06233	22 0	06230		AJP	0 GCT
	51 2	00C01		INI	2 1
06234	75 0	06240		SLJ	0 CCMPUT
	50 0	00C00		ENI	0 0
06235	22 0	06237	PICK	AJP	0 /+2
	51 2	00C01		INI	2 1
06236	75 0	06230		SLJ	0 GCT
	50 0	00C00		ENI	0 0
06237	10 0	00000		ENA	0 0
	20 0	06027		STA	0 ICCOUNT
06240	57 2	06066	COMPUT	SIL	2 HOLD
	10 2	00C00		ENA	2 0
06241	22 0	06322		AJP	0 LOCK
	16 0	06113		LDO	0 LCMASK
06242	44 3	16000		LDL	3 ALFA
	20 0	06602		STA	0 IAND
06243	55 2	06244		LJP	2 /+1
	75 0	06250		SLJ	0 PAT
06244	12 2	06603		LDA	2 AND
	75 4	06504		SLJ	4 SEARCH1
06245	50 0	00C00		ENI	0 0
	02 0	00C06		ARS	0 6
06246	21 2	06621		STO	2 LOCAT
	75 4	06511		SLJ	4 DECCUT
06247	20 2	06612		STA	2 PINNO
	75 0	06243		SLJ	0 /-4
06250	16 0	06113	BAT	LDO	0 LCMASK
	44 3	16C00		LDL	3 ALFA
06251	75 4	06504		SLJ	4 SEARCH1
	50 0	00C00		ENI	0 0
06252	02 0	00006		ARS	0 6
	21 0	06620		STO	0 OLOC
06253	12 0	06611		LDA	0 PINNI
	11 0	00C01		INA	0 1
06254	05 0	00C36		ALS	0 300
	17 0	06743		LJC	0 IMASK
06255	43 3	16000		SSU	3 ALFA
	20 3	16C00		STA	3 ALFA
06256	50 0	00C00		ENI	0 0
	04 0	00C00		ENO	0 0
06257	12 0	06747		LDA	0 INDIC
	20 0	05270		STA	0 OUTPUT+1
06260	53 2	06066		LIL	2 HOLD
	75 4	06327		SLJ	4 BEST
06261	12 0	06027		LDA	0 ICCOUNT
	22 1	06264		AJP	1 PREP
06262	51 3	00022		INI	3 22
	56 3	06263		SIU	3 /+1
06263	50 1	00C00		ENI	1 0
	50 0	00C00		ENI	0 0
06264	51 2	77776	PREP	INI	2 -1
	57 6	05311		SIL	6 BLTA
06265	04 0	00C00		ENO	0 0
	12 2	06717		LDA	2 TABLE
06266	07 0	00C06		LES	0 6
	20 0	05246		STA	0 TEMP+5
06267	21 0	05245		STO	0 TEMP+4

06270	53	6	05245
	12	6	06611
	22	0	06275
06271	75	4	06526
	50	0	00000
06272	03	0	00022
	12	6	06620
06273	14	0	06737
	07	0	00022
06274	75	0	06776
	50	0	00000
06275	12	6	06602
	14	0	06740
06276	20	0	05273
	50	0	00000
06277	12	6	06602
	14	0	06741
06300	20	0	05277
	12	0	05246
06301	04	0	00000
	07	0	00006
06302	21	0	05245
	53	6	05245
06303	12	6	06611
	22	0	06310
06304	75	4	06526
	50	0	00000
06305	03	0	00022
	12	6	06620
06306	14	0	06737
	07	0	00022
06307	75	0	06311
	50	0	00000
06310	12	6	06602
	14	0	06740
06311	20	0	05271
	50	0	00000
06312	12	6	06602
	14	0	06740
06313	05	0	00014
	20	0	05276
06314	16	0	06113
	44	2	06717
06315	75	4	06476
	50	0	00000
06316	20	0	05302
	12	0	06601
06317	20	0	05303
	53	6	05311
06320	75	0	06223
	50	0	00000
06321	72	0	06611
	75	0	06230
06322	12	3	16000
	22	0	06223
06323	12	3	16001
	22	1	06325
06324	12	0	07227
	20	0	05277
06325	51	3	00022
	56	3	06326
06326	50	1	00000
	75	0	06223
06327	75	0	00000
	57	6	06065
06330	10	0	00000
	50	6	00107
06331	20	6	06627
	55	6	06331
06332	20	0	05253
	75	4	06401
06333	55	2	06332
	12	0	06066

UDAT

LOOK

BEST

LIL	6	TEMP+4
LDA	6	PINNI
AJP	0	/+5
SLJ	4	CNVT
ENI	0	0
LRS	0	18D
LDA	6	OLOC
ADD	0	PRMSK
LLS	0	18D
SLJ	0	/+2
ENI	0	0
LDA	6	IAND
ADD	0	UPSPA
STA	0	OUTBUF+4
ENI	0	0
LDA	6	IAND
ADD	0	TCSPA
STA	0	OUTBUF+8D
LDA	0	TEMP+5
ENO	0	0
LLS	0	6
STQ	0	TEMP+4
LIL	6	TEMP+4
LDA	6	PINNI
AJP	0	/+5
SLJ	4	CNVT
ENI	0	0
LRS	0	18D
LDA	6	OLOC
ADD	0	PRMSK
LLS	0	18D
SLJ	0	/+2
ENI	0	0
LDA	6	IAND
ADD	0	UPSPA
STA	0	OUTBUF+2
ENI	0	0
LDA	6	IAND
ADD	0	UPSPA
ALS	0	12D
STA	0	OUTBUF+7
LDO	0	LOFASK
LDL	2	TABLE
SLJ	4	WIRE
ENI	0	0
STA	0	OUTBUF+11D
LDA	0	INCHES
STA	0	OUTBUF+12D
LIL	6	BETA
SLJ	0	GET
ENI	0	0
RAO	0	PINNI
SLJ	0	GOT
LDA	3	ALFA
AJP	0	GET
LDA	3	ALFA+1
AJP	1	/+2
LDA	0	CLOCK
STA	0	OUTBUF+8D
INI	3	22
SIU	3	/+1
ENI	1	0
SLJ	0	GET
SLJ	0	0
SIL	6	STORE
ENA	0	0
ENI	6	71D
STA	6	SINK
IJP	6	/
STA	0	FLAG
SLJ	4	POSITS
IJP	2	/-1
LDA	0	HOLD

06334	60 0	06451	SAU	0	DIAG+110
	11 0	77776	INA	0	-1
06335	60 0	06452	SAU	0	DIAG+120
	75 4	06436	SLJ	4	DIAG
06336	12 0	06066	LDA	0	HOLD
	57 2	05245	SIL	2	TEMP+4
06337	11 0	77776	INA	0	-1
	60 0	06376	SAU	0	ACCEPT+3
06340	16 0	07224	LDQ	0	BLOT
	51 2	77774	INI	2	=1
06341	50 0	00000	ENI	0	0
	44 2	06654	LDL	2	CHAIR
06342	22 1	06343	AJP	1	/+1
	55 2	06341	IJP	2	/-1
06343	04 6	00000	ENO	6	0
	23 1	06351	QJP	1	EARLY
06344	07 0	00006	LLS	0	6
	05 0	00006	ALS	0	6
06345	20 0	06735	STA	0	END1
	20 0	06726	STA	0	SUBTRE
06346	21 0	06736	STQ	0	END1+1
	21 0	06727	STQ	0	SUBTRE+1
06347	50 4	00002	ENI	4	2
	57 4	06067	SIL	4	WAIT
06350	75 0	06373	SLJ	0	ACCEPT
	50 0	00000	ENI	0	0
06351	04 0	00000	ENO	0	0
	07 0	00006	LLS	0	6
06352	05 0	00006	ALS	0	6
	50 0	00000	ENI	0	0
06353	64 4	06735	EOS	4	END1
	75 0	06361	SLJ	0	RAT
06354	57 4	05247	SIL	4	TEMP+6
	50 0	00000	ENI	0	0
06355	07 0	00060	LLS	0	480
	53 4	06067	LIL	4	WAIT
06356	64 4	06726	EOS	4	SUBTRE
	75 0	06367	SLJ	0	WEDO
06357	10 0	00000	ENA	0	0
	20 2	06654	STA	2	CHAIR
06360	20 0	05253	STA	0	FLAG
	75 0	06340	SLJ	0	MAINL
06361	53 4	05253	LIL	4	FLAG
	55 4	06365	IJP	4	SKIP
06362	07 0	00060	LLS	0	480
	50 4	00001	ENI	4	1
06363	57 4	05253	SIL	4	FLAG
	50 4	00002	ENI	4	2
06364	75 0	06353	SLJ	0	DGG
	50 0	00000	ENI	0	0
06365	57 4	05253	SIL	4	FLAG
	50 4	00002	ENI	4	2
06366	75 0	06340	SLJ	0	MAINL
	50 0	00000	ENI	0	0
06367	53 4	06067	LIL	4	WAIT
	20 4	06726	STA	4	SUBTRE
06370	53 4	05247	LIL	4	TEMP+6
	20 4	06735	STA	4	END1
06371	72 0	06067	RAO	0	WAIT
	10 0	00000	ENA	0	0
06372	20 0	05253	STA	0	FLAG
	50 0	00000	ENI	0	0
06373	12 2	06654	LDA	2	CHAIR
	20 6	06717	STA	6	TABLE
06374	10 0	00000	ENA	0	0
	20 2	06654	STA	2	CHAIR
06375	50 4	00002	ENI	4	2
	53 2	05245	LIL	2	TEMP+4
06376	54 6	00000	ISK	6	0
	75 0	06340	SLJ	0	MAINL
06377	53 2	06066	LIL	2	HOLD
	53 6	06065	LIL	6	STORE
06400	75 0	06327	SLJ	0	BEST

06401	50	0	00C00
	75	0	00C00
	04	0	00077
06402	44	2	06620
	22	0	06434
06403	64	0	06107
	75	0	06405
06404	10	0	00C00
	50	0	00G00
06405	20	0	05246
	06	0	00C06
06406	44	2	06620
	01	0	00C06
06407	64	0	06107
	75	0	06411
06410	10	0	00C00
	50	0	00G00
06411	24	0	06107
	70	0	05246
06412	24	0	06746
	20	2	06701
06413	16	0	07221
	44	2	06620
06414	22	1	06416
	10	0	00C11
06415	20	0	05246
	75	0	06417
06416	10	0	00C00
	20	0	05246
06417	16	0	07222
	44	2	06620
06420	22	0	06425
	10	0	00C07
06421	70	0	05246
	04	0	10C00
06422	44	2	06620
	22	0	06424
06423	10	0	00002
	75	0	06427
06424	10	0	00C01
	75	0	06427
06425	16	0	07223
	44	2	06620
06426	01	0	00C14
	50	0	00C00
06427	70	0	05246
	24	0	06744
06430	20	0	05246
	12	2	06611
06431	24	0	06745
	14	0	05246
06432	20	2	06710
	10	0	00C00
06433	75	0	06401
	50	0	00C00
06434	20	2	06701
	20	2	06710
06435	10	0	00C00
	75	0	06401
06436	75	0	00C00
	57	3	05246
06437	50	3	00C00
	50	6	00001
06440	12	6	06701
	15	2	06701
06441	20	0	05245
	24	0	05245
06442	20	0	05245
	12	6	06710
06443	15	2	06710
	20	0	05247
06444	24	0	05247
	70	0	05245

POSITS

NULOT

DIAC

ENI	0	0
SLJ	0	0
ENQ	0	77
LDL	2	OLCC
AJP	0	NULOT
FOS	0	ZERO
SLJ	0	/+2
ENA	0	0
ENI	0	0
STA	0	TEMP+5
OLS	0	6
LDL	2	OLCC
ARS	0	6
FOS	0	ZERO
SLJ	0	/+2
ENA	0	0
ENI	0	0
MUI	0	ZERO
RAD	0	TEMP+5
MUI	0	DCCL
STA	2	HCR
LDO	0	GLCP
LDL	2	OLCC
AJP	1	/+2
ENA	0	9D
STA	0	TEMP+5
SLJ	0	/+2
ENA	0	0
STA	0	TEMP+5
LDO	0	GLUM
LDL	2	OLCC
AJP	0	/+5
ENA	0	7
RAD	0	TEMP+5
ENQ	0	10C00
LDL	2	OLCC
AJP	0	/+1
ENA	0	2
SLJ	0	/+4
ENA	0	1
SLJ	0	/+3
LDO	0	BLUB
LDL	2	OLCC
ARS	0	12D
ENI	0	0
RAD	0	TEMP+5
MUI	0	ORON
STA	0	TEMP+5
LDA	2	PINNI
MUI	0	DPIN
ADD	0	TEMP+5
STA	2	VER
ENA	0	0
SLJ	0	POSITS
ENI	0	0
STA	2	HCR
STA	2	VER
ENA	0	0
SLJ	0	POSITS
SLJ	0	0
SIL	3	TEMP+5
ENI	3	0
ENI	6	1
LDA	6	HCR
SUB	2	HCR
STA	0	TEMP+4
MUI	0	TEMP+4
STA	0	TEMP+4
LDA	6	VER
SUB	2	VER
STA	0	TEMP+6
MUI	0	TEMP+6
RAD	0	TEMP+4

06445	10	6	00000
	05	0	00006
06446	11	2	00000
	05	0	00044
06447	14	0	05245
	20	3	06627
06450	51	3	00001
	50	0	00000
06451	54	6	00000
	75	0	06440
06452	54	2	00000
	75	0	06454
06453	51	3	77776
	75	0	06456
06454	57	2	05245
	53	6	05245
06455	51	6	00001
	75	0	06440
06456	57	3	05245
	72	0	05245
06457	16	0	07223
	10	3	00000
06460	11	0	06627
	61	0	06462
06461	60	0	06471
	50	0	00000
06462	53	6	05245
	44	0	00000
06463	67	6	06627
	75	0	06467
06464	57	6	07226
	10	0	06627
06465	14	0	07226
	60	0	06471
06466	44	6	06627
	75	0	06463
06467	52	5	06471
	12	5	00000
06470	20	2	06654
	10	0	00000
06471	20	0	00000
	51	2	00001
06472	55	3	06474
	53	3	05246
06473	75	0	06436
	50	0	00000
06474	53	5	06462
	56	5	06471
06475	75	0	06462
	50	0	00000
06476	75	0	00000
	50	0	00000
06477	57	6	06065
	50	6	00124
06500	65	6	07074
	75	0	06502
06501	12	6	06750
	75	0	06503
06502	12	0	07220
	50	0	00000
06503	53	6	06065
	75	0	06476
06504	75	0	00000
	04	0	00000
06505	57	6	06065
	53	6	06064
06506	64	6	10000
	75	0	06510
06507	16	6	15000
	50	0	00000
06510	53	6	06065
	75	0	06504
06511	75	0	00000

ORDER

VARI

LAMP

WIRE

SEARCH I

DECOUT

ENA	6	0
ALS	0	6
INA	2	0
ALS	0	36D
ADD	0	TEMP+4
STA	3	SINK
INI	3	1
ENI	0	0
ISK	6	0
SLJ	0	DIAG+2
ISK	2	0
SLJ	0	7+2
INI	3	-1
SLJ	0	ORDER
SIL	2	TEMP+4
LIL	6	TEMP+4
INI	6	1
SLJ	0	DIAG+2
SIL	3	TEMP+4
RAO	0	TEMP+4
LDO	0	BLAM
ENA	3	0
INA	0	SINK
SAL	0	7+2
SAU	0	VARI
ENI	0	0
LIL	6	TEMP+4
LDL	0	0
MTH	6	SINK
SLJ	0	7+4
SIL	6	GOFFER
ENA	0	SINK
ADD	0	GOFFER
SAU	0	VARI
LDL	6	SINK
SLJ	0	7-3
LIU	5	VARI
LDA	5	0
STA	2	CHAIR
ENA	0	0
STA	0	0
INI	2	1
IJP	3	LAMP
LIL	3	TEMP+5
SLJ	0	DIAG
ENI	0	0
LIL	5	ORDER+4
SIU	5	VARI
SLJ	0	ORDER+4
ENI	0	0
SLJ	0	0
ENI	0	0
SIL	6	STORE
ENI	6	84D
IHS	6	APPX
SLJ	0	7+2
LDA	6	TYPE
SLJ	0	7+2
LDA	0	MAX
ENI	0	0
LIL	6	STORE
SLJ	0	WIRE
ENI	0	0
SIL	6	STORE
LIL	6	COUNT
EQS	6	ARGUE
SLJ	0	7+2
LDO	6	VALUE
ENI	0	0
LIL	6	STORE
SLJ	0	SEARCH I
SLJ	0	0

06512	57	6	06065
	53	6	05242
	16	0	06113
06513	66	6	16000
	75	0	06524
06514	16	0	06742
	44	6	16000
06515	22	1	06517
	12	2	06603
06516	16	6	06113
	75	0	06513
06517	01	0	00030
	20	0	06067
06520	11	0	77776
	05	0	00030
06521	17	0	06742
	43	6	16000
06522	20	6	16000
	12	0	06067
06523	75	0	06525
	50	0	00000
06524	10	0	00000
	50	0	00000
06525	53	6	06065
	75	0	06511
06526	75	0	00000
	57	6	06065
06527	50	6	00011
	04	0	00077
06530	66	6	06542
	75	0	06532
06531	75	0	06537
	50	0	00000
06532	15	0	06541
	22	3	06534
06533	12	0	06555
	75	0	06540
06534	11	0	00001
	22	3	06536
06535	12	0	06554
	75	0	06540
06536	12	0	06553
	75	0	06540
06537	12	6	06542
	50	0	00000
06540	53	6	06065
	75	0	06526
06541	00	0	00000
	00	0	00014
06542	00	0	00000
	00	4	01201
06543	00	0	00000
	00	4	01202
06544	00	0	00000
	00	4	01203
06545	00	0	00000
	00	4	01204
06546	00	0	00000
	00	4	01205
06547	00	0	00000
	00	4	01206
06550	00	0	00000
	00	4	01207
06551	00	0	00000
	00	4	01210
06552	00	0	00000
	00	4	01211
06553	00	0	00000
	00	4	00112
06554	00	0	00000
	00	4	00101
06555	00	0	00000
	00	4	00102

CNVT

RAW

FORTN

BACK

SIL	6	STORE
LIL	6	TEMP+1
LDO	0	LOMASK
MEQ	6	ALFA
SLJ	0	/+9D
LDO	0	OMASK
LDL	6	ALFA
AJP	1	/+2
LDA	2	AND
LDO	0	LOMASK
SLJ	0	/-3
ARS	0	24D
STA	0	WAIT
INA	0	-1
ALS	0	24D
LQC	0	OMASK
SSU	6	ALFA
STA	6	ALFA
LDA	0	WAIT
SLJ	0	/+2
ENI	0	0
ENA	0	0
ENI	0	0
LIL	6	STORE
SLJ	0	DECOUT
SLJ	0	0
SIL	6	STORE
ENI	6	9D
END	0	77
MEQ	6	BACK
SLJ	0	/+2
SLJ	0	/+6
ENI	0	0
SUB	0	FORTN
AJP	3	/+2
LDA	0	BACK+11D
SLJ	0	RAW
INA	0	1
AJP	3	/+2
LDA	0	BACK+10D
SLJ	0	RAW
LDA	0	BACK+9D
SLJ	0	RAW
LDA	6	BACK
ENI	0	0
LIL	6	STORE
SLJ	0	CNVT
OCT	14	
OCT	401201	
OCT	401202	
OCT	401203	
OCT	401204	
OCT	401205	
OCT	401206	
OCT	401207	
OCT	401210	
OCT	401211	
OCT	400112	
OCT	400101	
OCT	400102	

06556	00 0 00000	LENGTH	DEC	4
06557	00 0 00004	LENGTH5	DEC	110
06560	00 0 00013	HEAD4	BCD	/
06561	20 2 02020		BCD	/INTER CA
06562	71 4 52365		BCD	/RD WIRIN
06563	51 2 06361		BCD	/G TABULA
06564	51 6 42026		BCD	/TION
06565	71 4 17145	HEAD5	BCD	/
06566	67 2 02361		BCD	/ ORIGIN
06567	62 2 44361		BCD	/
06570	23 7 14645		BCD	/DESTINAI
06571	20 2 02020		BCD	/IGN
06572	20 2 02020		BCD	/
06573	20 2 02020		BCD	/ DESIG
06574	65 2 27167		BCD	/NATIONS
06575	45 6 12371		BCD	/
06576	46 4 52220		BCD	/
06577	20 2 02020		BCD	/WIRE LEN
06600	20 2 02020		BCD	/GTH
06601	67 2 37020	INCHES	BCD	/INCHES
06602	20 2 02020	LAND	BSS	1
06603	71 4 56370	AND	BSS	6
06611	65 2 22020	PINVI	BSS	1
06612	00 0 00000	PINVO	BSS	6
06620	00 0 00000	OLOC	BSS	1
06621	00 0 00000	LOCAT	BSS	6
06627	00 0 00000	SINK	BSS	210
06654	00 0 00000	CHAIR	BSS	210
06701	00 0 00000	HOR	BSS	7
06710	00 0 00000	VER	BSS	7
06717	00 0 00000	TABLE	BSS	7
06726	00 0 00000	SUBTRE	BSS	7
06735	00 0 00000	END1	BSS	2
06737	00 0 00020	PRMSK	OCT	2020000000
06740	20 0 00000	UPSPA	OCT	2020202000000000
06741	20 2 02020	TOSPA	OCT	2346202000000000
06742	23 4 62020	OMASK	OCT	7700000000

06743	00 0 00000	IMASK	CCT	770000000000
	00 0 07700			
	00 0 00000			
06744	00 0 00000	DROW	DEC	38
	00 0 00046			
06745	00 0 00000	DPIN	DEC	2
	00 0 00002			
06746	00 0 00000	DCOL	DEC	5
	00 0 00005			
06747	20 2 02020	INDIG	BCD	/
	20 2 02020			
06750	04 0 32020	TYPE	BCD	/43
	20 2 02020			
06751	04 0 22001		BCD	/42 1/2
	21 0 22020			
06752	04 0 22020		BCD	/42
	20 2 02020			
06753	04 0 12001		BCD	/41 1/2
	21 0 22020			
06754	04 0 12020		BCD	/41
	20 2 02020			
06755	04 1 22001		BCD	/40 1/2
	21 0 22020			
06756	04 1 22020		BCD	/40
	20 2 02020			
06757	03 1 12001		BCD	/39 1/2
	21 0 22020			
06760	03 1 12020		BCD	/39
	20 2 02020			
06761	03 1 02001		BCD	/38 1/2
	21 0 22020			
06762	03 1 02020		BCD	/38
	20 2 02020			
06763	03 0 72001		BCD	/37 1/2
	21 0 22020			
06764	03 0 72020		BCD	/37
	20 2 02020			
06765	03 0 62001		BCD	/36 1/2
	21 0 22020			
06766	03 0 62020		BCD	/36
	20 2 02020			
06767	03 0 52001		BCD	/35 1/2
	21 0 22020			
06770	03 0 52020		BCD	/35
	20 2 02020			
06771	03 0 42001		BCD	/34 1/2
	21 0 22020			
06772	03 0 42020		BCD	/34
	20 2 02020			
06773	03 0 32001		BCD	/33 1/2
	21 0 22020			
06774	03 0 32020		BCD	/33
	20 2 02020			
06775	03 0 22001		BCD	/32 1/2
	21 0 22020			
06776	03 0 22020		BCD	/32
	20 2 02020			
06777	03 0 12001		BCD	/31 1/2
	21 0 22020			
07000	03 0 12020		BCD	/31
	20 2 02020			
07001	03 1 22001		BCD	/30 1/2
	21 0 22020			
07002	03 1 22020		BCD	/30
	20 2 02020			
07003	02 1 12001		BCD	/29 1/2
	21 0 22020			
07004	02 1 12020		BCD	/29
	20 2 02020			
07005	02 1 02001		BCD	/28 1/2
	21 0 22020			
07006	02 1 02020		BCD	/28
	20 2 02020			

07007	02 0 72001	BCD	/27 1/2
	21 0 22020		
07010	02 0 72020	BCD	/27
	20 2 02020		
07011	02 0 62001	BCD	/26 1/2
	21 0 22020		
07012	02 0 62020	BCD	/26
	20 2 02020		
07013	02 0 52001	BCD	/25 1/2
	21 0 22020		
07014	02 0 52020	BCD	/25
	20 2 02020		
07015	02 0 42001	BCD	/24 1/2
	21 0 22020		
07016	02 0 42020	BCD	/24
	20 2 02020		
07017	02 0 32001	BCD	/23 1/2
	21 0 22020		
07020	02 0 32020	BCD	/23
	20 2 02020		
07021	02 0 22001	BCD	/22 1/2
	21 0 22020		
07022	02 0 22020	BCD	/22
	20 2 02020		
07023	02 0 12001	BCD	/21 1/2
	21 0 22020		
07024	02 0 12020	BCD	/21
	20 2 02020		
07025	02 1 22001	BCD	/20 1/2
	21 0 22020		
07026	02 1 22020	BCD	/20
	20 2 02020		
07027	01 1 12001	BCD	/19 1/2
	21 0 22020		
07030	01 1 12020	BCD	/19
	20 2 02020		
07031	01 1 02001	BCD	/18 1/2
	21 0 22020		
07032	01 1 02020	BCD	/18
	20 2 02020		
07033	01 0 72001	BCD	/17 1/2
	21 0 22020		
07034	01 0 72020	BCD	/17
	20 2 02020		
07035	01 0 62001	BCD	/16 1/2
	21 0 22020		
07036	01 0 62020	BCD	/16
	20 2 02020		
07037	01 0 52001	BCD	/15 1/2
	21 0 22020		
07040	01 0 52020	BCD	/15
	20 2 02020		
07041	01 0 42001	BCD	/14 1/2
	21 0 22020		
07042	01 0 42020	BCD	/14
	20 2 02020		
07043	01 0 32001	BCD	/13 1/2
	21 0 22020		
07044	01 0 32020	BCD	/13
	20 2 02020		
07045	01 0 22001	BCD	/12 1/2
	21 0 22020		
07046	01 0 22020	BCD	/12
	20 2 02020		
07047	01 0 12001	BCD	/11 1/2
	21 0 22020		
07050	01 0 12020	BCD	/11
	20 2 02020		
07051	01 1 22001	BCD	/10 1/2
	21 0 22020		
07052	01 1 22020	BCD	/10
	20 2 02020		
07053	20 1 12001	BCD	/ 9 1/2

07054	2100	00	22020
	2000	21	12020
07055	2000	10	02020
	2100	00	02001
07056	2000	00	02020
	2000	21	02020
07057	2000	00	72001
	2100	00	22020
07060	2000	00	72020
	2000	21	02020
07061	2000	00	62001
	2100	00	22020
07062	2000	00	62020
	2000	21	02020
07063	2000	00	52001
	2100	00	22020
07064	2000	00	52020
	2000	21	02020
07065	2000	00	42001
	2100	00	22020
07066	2000	00	42020
	2000	21	02020
07067	2000	00	32001
	2100	00	22020
07070	2000	00	32020
	2000	21	02020
07071	2000	00	22001
	2100	00	22020
07072	2000	00	22020
	2000	21	02020
07073	2000	00	12001
	2100	00	22020
07074	2000	00	00000
	2000	01	53544
07075	2000	00	00000
	2000	01	36426
07076	2000	00	00000
	2000	01	21430
07077	2000	00	00000
	2000	01	04554
07100	2000	00	00000
	2000	07	70020
07101	2000	00	00000
	2000	07	53405
07102	2000	00	00000
	2000	07	37112
07103	2000	00	00000
	2000	07	22740
07104	2000	00	00000
	2000	07	06706
07105	2000	00	00000
	2000	06	72776
07106	2000	00	00000
	2000	06	57206
07107	2000	00	00000
	2000	06	43537
07110	2000	00	00000
	2000	06	30210
07111	2000	00	00000
	2000	06	15002
07112	2000	00	00000
	2000	06	01714
07113	2000	00	00000
	2000	05	66747
07114	2000	00	00000
	2000	05	54123
07115	2000	00	00000
	2000	05	41420
07116	2000	00	00000
	2000	05	27035
07117	2000	00	00000
	2000	05	14573

BCD	/ 9
BCD	/ 8 1/2
BCD	/ 8
BCD	/ 7 1/2
BCD	/ 7
BCD	/ 6 1/2
BCD	/ 6
BCD	/ 5 1/2
BCD	/ 5
BCD	/ 4 1/2
BCD	/ 4
BCD	/ 3 1/2
BCD	/ 3
BCD	/ 2 1/2
BCD	/ 2
BCD	/ 1 1/2
APRX DEC	284516
DEC	277782
DEC	271128
DEC	264556
DEC	258064
DEC	251653
DEC	245322
DEC	239072
DEC	232902
DEC	226814
DEC	220806
DEC	214879
DEC	209032
DEC	203266
DEC	197580
DEC	191975
DEC	186451
DEC	181008
DEC	175645
DEC	170366

07120	00 0 00000	DEC	165161
	00 5 02451		
07121	00 0 00000	DEC	160040
	00 4 70450		
07122	00 0 00000	DEC	155000
	00 4 56570		
07123	00 0 00000	DEC	150040
	00 4 45030		
07124	00 0 00000	DEC	145161
	00 4 33411		
07125	00 0 00000	DEC	140364
	00 4 22113		
07126	00 0 00000	DEC	135645
	00 4 10735		
07127	00 0 00000	DEC	131008
	00 3 77700		
07130	00 0 00000	DEC	126457
	00 3 66771		
07131	00 0 00000	DEC	121976
	00 3 56170		
07132	00 0 00000	DEC	117580
	00 3 45514		
07133	00 0 00000	DEC	113266
	00 3 35162		
07134	00 0 00000	DEC	109032
	00 3 24750		
07135	00 0 00000	DEC	104879
	00 3 14657		
07136	00 0 00000	DEC	100806
	00 3 04706		
07137	00 0 00000	DEC	96814
	00 2 75056		
07140	00 0 00000	DEC	92903
	00 2 65347		
07141	00 0 00000	DEC	89072
	00 2 55760		
07142	00 0 00000	DEC	85322
	00 2 46512		
07143	00 0 00000	DEC	81653
	00 2 37365		
07144	00 0 00000	DEC	78064
	00 2 30360		
07145	00 0 00000	DEC	74556
	00 2 21474		
07146	00 0 00000	DEC	71129
	00 2 12731		
07147	00 0 00000	DEC	67782
	00 2 04306		
07150	00 0 00000	DEC	64516
	00 1 76004		
07151	00 0 00000	DEC	61331
	00 1 67623		
07152	00 0 00000	DEC	58227
	00 1 61563		
07153	00 0 00000	DEC	55202
	00 1 53642		
07154	00 0 00000	DEC	52258
	00 1 46042		
07155	00 0 00000	DEC	49395
	00 1 40363		
07156	00 0 00000	DEC	46613
	00 1 33025		
07157	00 0 00000	DEC	43911
	00 1 25607		
07160	00 0 00000	DEC	41290
	00 1 20512		
07161	00 0 00000	DEC	38750
	00 1 13536		
07162	00 0 00000	DEC	36290
	00 1 06702		
07163	00 0 00000	DEC	33911
	00 1 02167		
07164	00 0 00000	DEC	31613

07165	00 0 75575		DEC	29395
	00 0 00C00			
	00 0 71323			
07166	00 0 00C00		DEC	27258
	00 0 65172			
07167	00 0 00C00		DEC	25202
	00 0 61162			
07170	00 0 00C00		DEC	23226
	00 0 55272			
07171	00 0 00C00		DEC	21241
	00 0 51523			
07172	00 0 00C00		DEC	19516
	00 0 46074			
07173	00 0 00C00		DEC	17782
	00 0 42566			
07174	00 0 00C00		DEC	16129
	00 0 37401			
07175	00 0 00C00		DEC	14556
	00 0 34334			
07176	00 0 00C00		DEC	13064
	00 0 31410			
07177	00 0 00C00		DEC	11653
	00 0 26605			
07200	00 0 00C00		DEC	10323
	00 0 24123			
07201	00 0 00C00		DEC	9073
	00 0 21561			
07202	00 0 00C00		DEC	7903
	00 0 17337			
07203	00 0 00C00		DEC	6815
	00 0 15237			
07204	00 0 00C00		DEC	5806
	00 0 13256			
07205	00 0 00C00		DEC	4879
	00 0 11417			
07206	00 0 00C00		DEC	4032
	00 0 07700			
07207	00 0 00C00		DEC	3266
	00 0 06302			
07210	00 0 00C00		DEC	2581
	00 0 05025			
07211	00 0 00C00		DEC	1976
	00 0 03670			
07212	00 0 00C00		DEC	1452
	00 0 02654			
07213	00 0 00C00		DEC	1008
	00 0 01760			
07214	00 0 00C00		DEC	645
	00 0 01205			
07215	00 0 00C00		DEC	363
	00 0 00553			
07216	00 0 00C00		DEC	137
	00 0 00211			
07217	00 0 00C00		DEC	70
	00 0 00106			
07220	04 0 36020	MAX	BCD	/43+
	20 2 02020			
07221	00 0 00C00	GLOP	OCT	200000
	00 2 00C00			
07222	00 0 00C00	GLUN	OCT	100000
	00 1 00C00			
07223	00 0 07777	BLAN	OCT	0000777777777777
	77 7 77777			
07224	77 7 70C00	BLOT	OCT	7777000000000000
	00 0 00C00			
07225	00 0 00C00	BLUB	OCT	70000
	00 0 70C00			
07226	00 0 00C00	GOFER	OCT	0
	00 0 00C00			
07227	20 2 02063	CLOCK	BCD	/ CLOCK
	43 4 66342			
		ARGUE	EQU	10000
		VALLE	EQU	13000

.ALFA

EQU
END

16000

CHAPTER II

GENERAL DATA CONFIGURATION IN THE AN OUTLET CODING AND CONTROL BLUES

A. 154

1. Coding

The external function instruction (74) acts in three different modes to give (a) activation of a channel; (b) sensing of a condition at an external equipment or (c) selecting an external equipment to communicate with the computer.

The channel activate sub-instructions 74.1 through 74.6 are interpreted as follows:

74	1 thru 6	Base Execution Address
6 bit operation code	3 bit index (channel) designator	15 bits which specifies the initial address for data storage in buffering operation

The sense sub-instruction 74.7 is interpreted as follows:

74	7	1 thru 7	1 thru 7	
sense		3 bit channel selection code	3 bits external equipment code	3 bits condition code which specifies operation being sensed

1. If the sensed condition is met, a full exit from the word is performed. If the sensed condition is not met, a half exit from the word is performed.

The Select Sub-instruction 70.0 is interpreted as follows:

70	0	1 thru 7		
6 bit operation index code	3 bit channel selection code	3 bits channel selection code	7 bits exte- nal equipment code	9 bits condition code which speci- fies operation being selected
Select				

2. Data and Control Lines

Input equipment to computer

input data Comprise two complete cables and two
(48 lines) lines of a third cable of a buffer or
transfer cable group

Input data Function: Indicates equipment input register
ready (1 line) contains information which computer
may sample.

Operation: Turned off by input data resume from
computer. (Computer resync circuitry
orients itself about leading edge of
ready signal; auxiliary scanner is
stopped and input word is passed to
computer.)

Computer to Input Equipment

Input data Function: Indicates to equipment that computer
resume (1 line) has accepted input word.

Operation: Turned off by input data ready; turned
on when computer has accepted and
stores input word.

Computer to Output Equipment

Output (48 lines) Comprise two complete cables and two lines of a third cable or a buffer or transfer cable group.

Output data Function: Accompanies output data from computer.
ready (1 line) Operation: Turned on when computer has word of information ready for equipment; off by resume from equipment.

Output Equipment to Computer

Output data Function: Indicates that equipment has accepted word.
resume (1 line)

Operation: Turned on when equipment has accepted word. (Computer resync circuitry orients itself about the trailing edge of resume; when signal drops auxiliary scanner stops and another word is exchanged. Computer prepares a word for exchange while output data resume signal is up.)

Computer to External Equipment

External function Function: Carries external function (AF) codes to select or sense a condition within the equipment
(12 lines)

Operation: Lines continuously monitored by all equipment. Appropriate function or sense ready alerts equipment on a

lines.
lines.

External Master Function: Clears and enables on all channels.

clear (1 line) Operation: Occurs when clear switch at console is in up position.

External Equipment to Computer

Sense response Function: Indicates equipment's reply to sense code.

Operation: ON indicates presence of condition specified by sense code; OFF indicates absence of condition.

Interrupt (1 line) Operation: External equipment or internal computer control sends signal when a condition arises that was previously selected by a 74.4.

Computer to Input Equipment

Input Function Function: Accompanies LR Select code

Ready (1 line) Operation: Turned on by instruction 74.6. Causes input equipment to translate LR code.

Input sense Function: Accompanies LR Sense Code

Ready (1 line) Operation: Turned on by instruction 74.7. Causes input equipment to translate LR code and send response back to computer.

Input Buffer Function: Indicates computer is prepared to receive a block of data.

Operation: Turned on when input buffer channel

is activated by instruction 74.1, 74.3 or 74.5. Remains on until final word of block is entered in storage.

Computer to Output Equipment

Output Function Function: Accompanies M' select code.
Ready (1 line)

Operation: Turned on by instruction 74.0. Causes output equipment to translate M' code.

Output Sense Function: Accompanies M' sense code.
Ready (1 line)

Operation: Turned on by instruction 74.7. Causes output equipment to translate M' code and send response back to computer.

Output Buffer Function: Indicates computer is prepared to
Active (1 line) transmit a block of data.

Operation: Turned on when output buffer channel is activated by instructions 74.2, 74.4, or 74.6. Remains on until final word of block is transmitted to output equipment.

B. 160

1. Coding

The computer controls the operation of its external equipment by issuing 12 bit function codes. This process, initiated by the external function (75) instruction, places a designated 12-bit code on the output lines and activates the function ready signal. Each external equipment receives the data, but only the equipment recognizing it responds to it by sending back a function resume signal.

The primary control computer is built into the host, at least one of the input functions which may be used to set the status of the host from the external equipment. The equipment must be designed to place a 12-bit status response code on the input cable. The host must then process this response through an input instruction INI (70) which will bring the 12 bits into the "A" register. The status response must be a one out of twelve response for each condition as more than one condition may exist. This allows for only twelve possible conditions for design to be designed into any external equipment.

Normal input and output are handled by the INT (71) and OUT (73) commands respectively. These operate on blocks of memory.

2. Data and Control Lines

INOUT	FUNCTION
12 Data Lines	
Input Data and	Normal purpose:
Input Status	1) As data lines they hold equipment input re-
(12 lines)	gister contents which the computer may sample.
	2) As input status lines they indicate equip-
	ment's response to status request interroga-
	tion.
Input ready	Indicates that the external equipment contains
(1 line)	information which the computer may sample.
	(Computer resync circuits are oriented about the
	leading edge of the ready signal.)
Input request	Indicates to external equipment that computer

(1 line) The computer input word. This word is to be read if the input ready.

Input Disconnect Indicates to computer that input device has no more data to deliver. Computer is then free to resume main program with no further delay.

(1 line) (Generally the input instruction establishes a storage field block of greater capacity than the information block.)

OUTPUT

GENERAL LINE

FUNCTIONS

Output Data and Continuously monitored by line equipment.

Output Function Dual purpose:

(12 lines) 1) As output data lines they hold output word which the external device may sample.

 2) As output function lines they carry external function (as) codes to select or sense a condition within the equipment. Function ready alerts the equipment to sample the data code.

Function Ready Accompanies data code. It is turned on by instruction 73 to allow the equipment to sample the data code. It is turned off by instruction 74 to release from the external equipment.

(1 line)

Information This signal accompanies the output data word from the computer. It is turned on when the computer has a word of information ready for the

Ready

(1 line)

external equipment. It is turned off by an output resume from the equipment.

Output Resume

(1 line)

This signal is turned on when the external device has accepted the output word or address code. (The computer resync circuitry orients itself about the trailing edge of the resume; when the signal drops the word is exchanged.) The computer prepares a word while the signal is up.

Master Clear

(1 line)

This signal clears all external equipment. It occurs when the Load-Clear switch at the console is in the Clear (down) position.

000003
FE 20 64
20 AUG 66
25 JUL 67

BINDERY
BINDERY
13920
14814
16550

Thesis

L334 Lawson

57143

An integrated display
and control system for
man-machine communication

FE 20 64
20 AUG 66
25 JUL 67

BINDERY
13920
14814
16550

Thesis

L334 Lawson

57143

An integrated display
and control system for
man-machine communication.

thesL334

An integrated display and control system



3 2768 002 1125 4

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